US009203464B2

(12) **United States Patent**
**Kim et al.**

(10) **Patent No.: US 9,203,464 B2**
(45) **Date of Patent: Dec. 1, 2015**

(54) **COMMUNICATION APPARATUS AND COMMUNICATION METHOD IN WIRELESS POWER TRANSMISSION SYSTEM**

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(73) Assignee: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 695 days.

(21) Appl. No.: **13/603,826**

(22) Filed: **Sep. 5, 2012**

(65) **Prior Publication Data**

US 2013/0058380 A1 Mar. 7, 2013

(30) **Foreign Application Priority Data**

Sep. 5, 2011 (KR) ..... 10-2011-0089396
Oct. 27, 2011 (KR) ..... 10-2011-0110531

(51) **Int. Cl.**

***H04B 1/707*** (2011.01)
***H04W 16/14*** (2009.01)
***H04W 24/00*** (2009.01)
*H04W 72/08* (2009.01)
*H04W 76/02* (2009.01)

(52) **U.S. Cl.**

CPC ..... ***H04B 1/707*** (2013.01); ***H04W 16/14*** (2013.01); *H04W 24/00* (2013.01); *H04W 72/085* (2013.01); *H04W 76/023* (2013.01)

(58) **Field of Classification Search**

CPC ..... H04B 1/707; H02W 16/14; H02W 24/00; H02W 72/085; H02W 76/023
USPC ..... 307/104
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0042595 A1 2/2009 Yavuz et al.
2011/0021153 A1 1/2011 Safavi
2011/0080896 A1 4/2011 Krishnamurthy et al.

(Continued)

FOREIGN PATENT DOCUMENTS

KR 10-2010-0029245 A 3/2010
KR 10-2011-0009228 A 1/2011

(Continued)

OTHER PUBLICATIONS

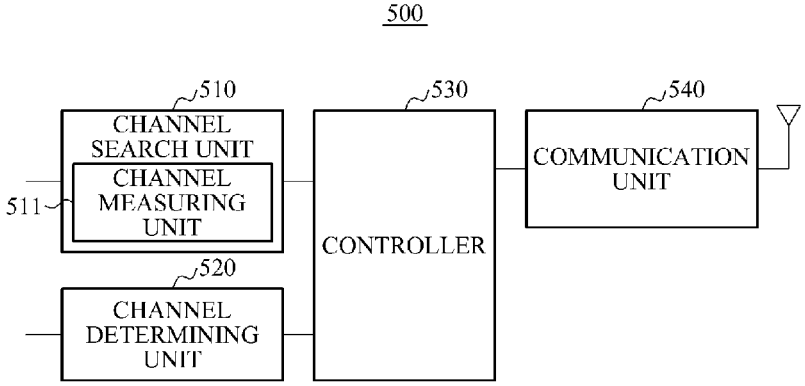
International Search Report issued Feb. 27, 2013 in counterpart International Application No. PCT/KR2012/006479 (5 pages in English).

*Primary Examiner* — Hal Kaplan
(74) *Attorney, Agent, or Firm* — NSIP Law

(57) **ABSTRACT**

An apparatus and method for performing communication in a wireless power transmission system are provided. The apparatus includes a channel search unit configured to search for communication channels other than a channel used in wireless power transmission, and measure state information of the communication channels. The apparatus includes a channel determining unit configured to determine a communication channel available for communication with a target device based on the measured state information. The apparatus includes a communication unit configured to transmit an access instruction to the target device using the determined communication channel. The apparatus includes a controller configured to determine whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access instruction is received.

**36 Claims, 30 Drawing Sheets**



(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0127843 A1 6/2011 Karaoguz et al.
2011/0127952 A1 6/2011 Walley et al.
2011/0142150 A1 6/2011 Anigstein et al.
2011/0154087 A1 6/2011 Craine

FOREIGN PATENT DOCUMENTS

KR 10-2011-0026205 A 3/2011
KR 10-2011-0050396 A 5/2011
KR 10-2011-0069890 A 6/2011

FIG. 1

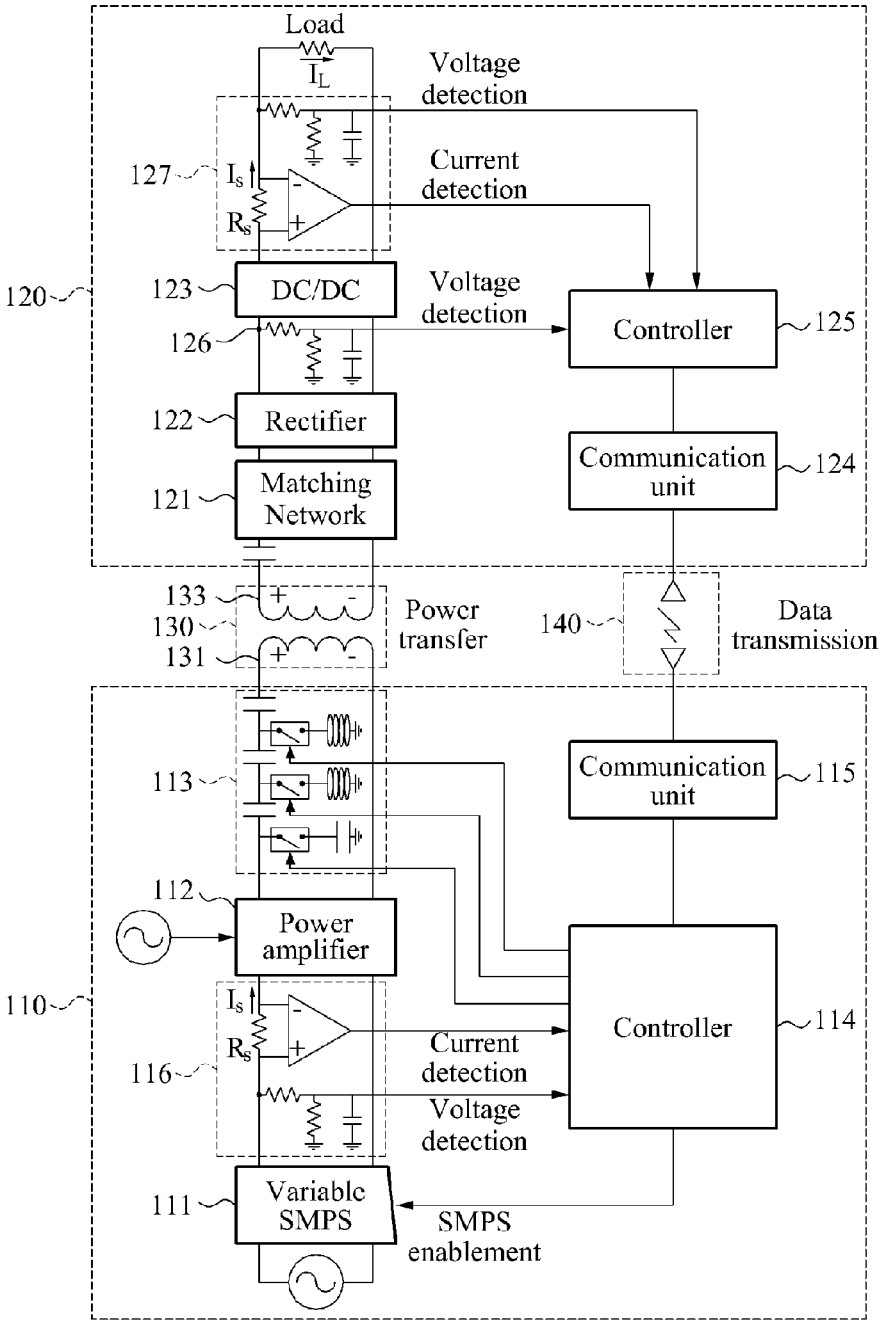

Load
$I_L$
Voltage detection
Current detection
127
$I_s$
$R_s$
120
123
DC/DC
Voltage detection
Controller
125
126
122
Rectifier
Communication unit
124
121
Matching Network
133
130
131
Power transfer
140
Data transmission
113
Communication unit
115
112
Power amplifier
110
$I_s$
$R_s$
Controller
114
Current detection
116
Voltage detection
111
Variable SMPS
SMPS enablement

**FIG. 2**

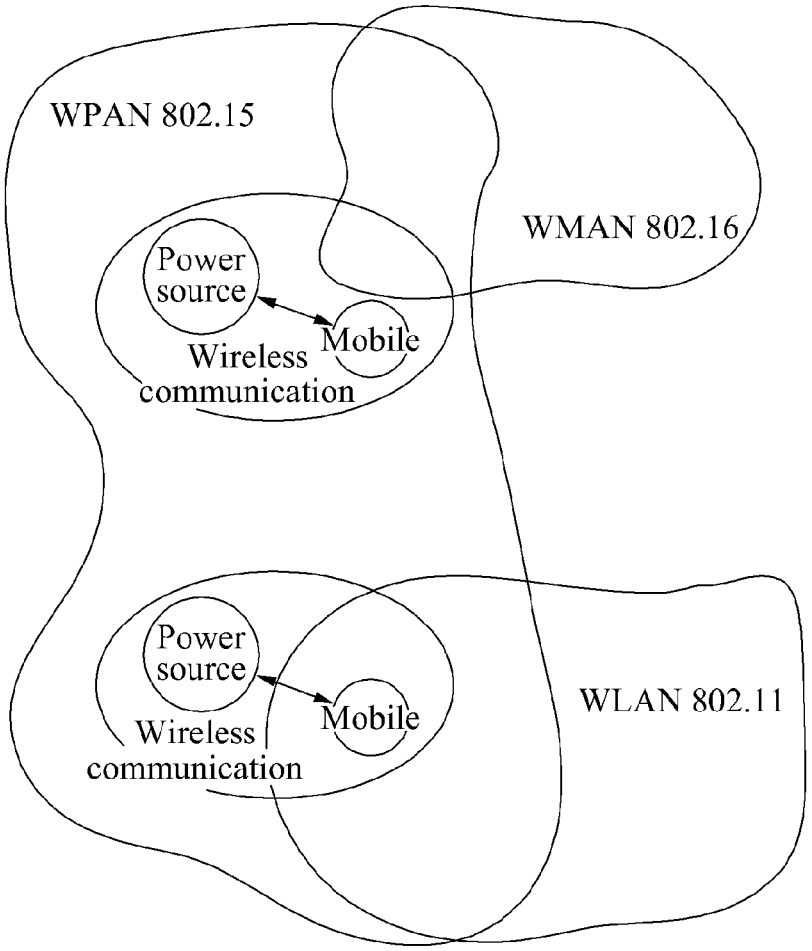

WPAN 802.15
WMAN 802.16
Power source
Mobile
Wireless communication
Power source
Mobile
Wireless communication
WLAN 802.11

FIG. 3

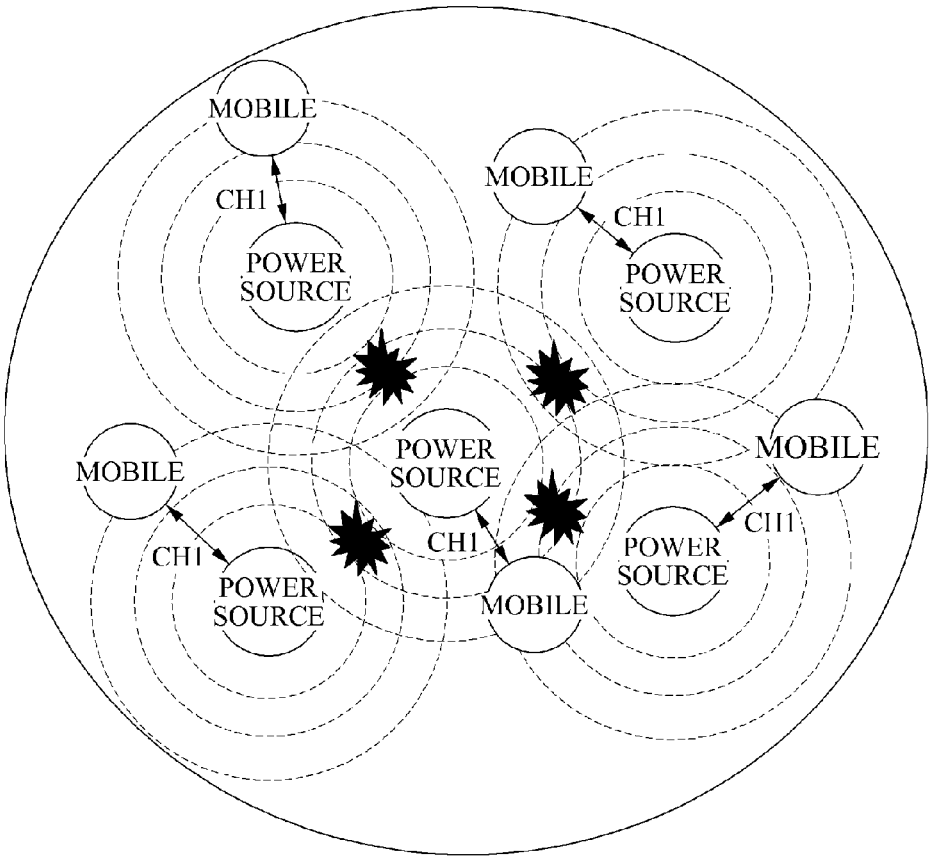

MOBILE
CH1
POWER SOURCE
MOBILE
CH1
POWER SOURCE
MOBILE
CH1
POWER SOURCE
POWER SOURCE
MOBILE
CH1
POWER SOURCE
MOBILE
CH1
POWER SOURCE
MOBILE

FIG. 4

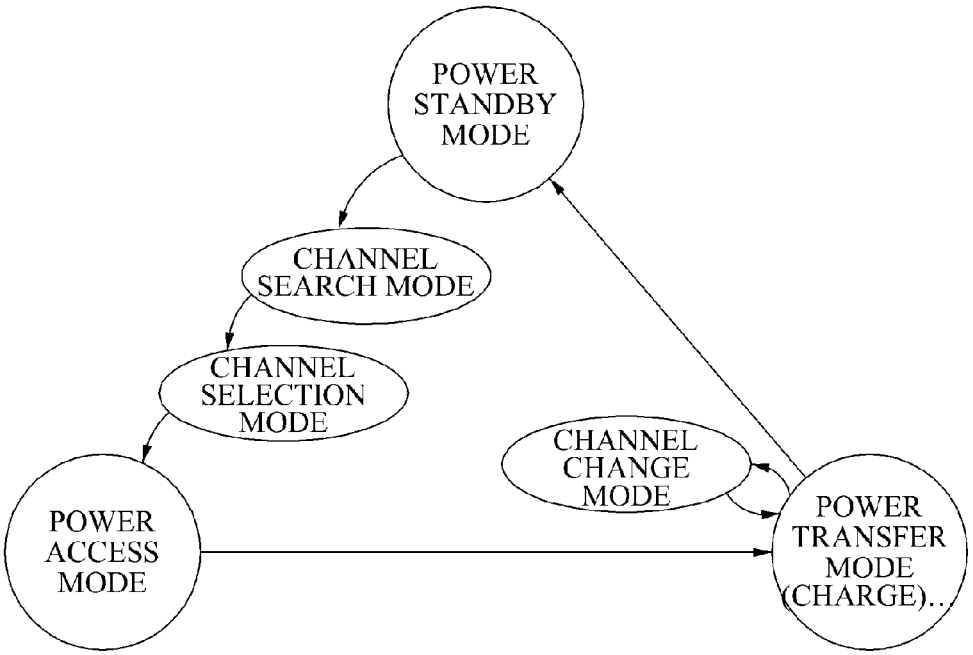

POWER STANDBY MODE
CHANNEL SEARCH MODE
CHANNEL SELECTION MODE
CHANNEL CHANGE MODE
POWER ACCESS MODE
POWER TRANSFER MODE (CHARGE)...

FIG. 5

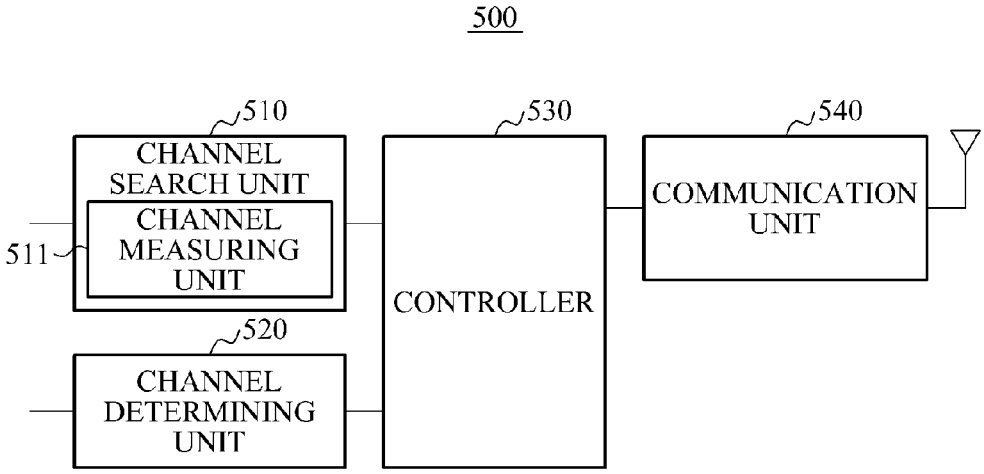

500
510
CHANNEL SEARCH UNIT
CHANNEL MEASURING UNIT
511
520
CHANNEL DETERMINING UNIT
530
CONTROLLER
540
COMMUNICATION UNIT

FIG. 6

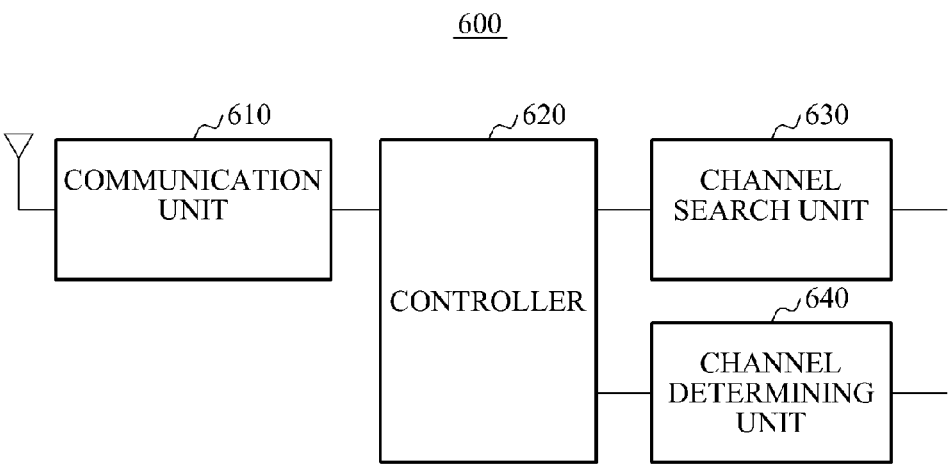

600
610
COMMUNICATION UNIT
620
CONTROLLER
630
CHANNEL SEARCH UNIT
640
CHANNEL DETERMINING UNIT

FIG. 7

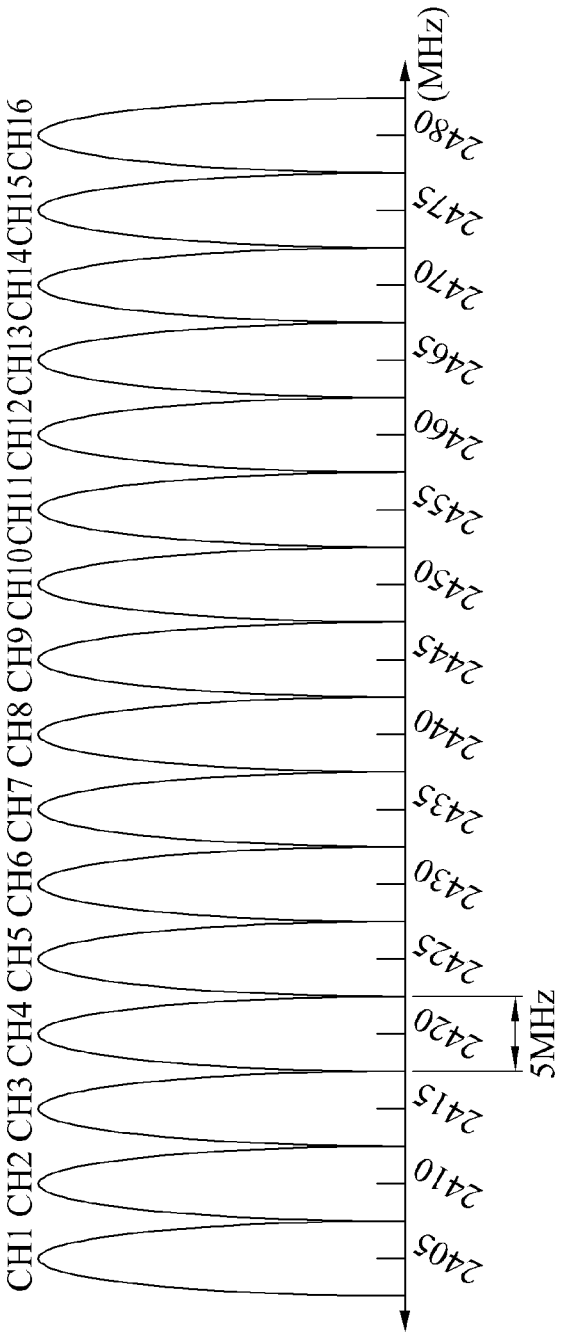

(MHz)
2480
2475
2470
2465
2460
2455
2450
2445
2440
2435
2430
2425
2420
2415
2410
2405
5MHz
CH1 CH2 CH3 CH4 CH5 CH6 CH7 CH8 CH9 CH10 CH11 CH12 CH13 CH14 CH15 CH16

FIG. 8

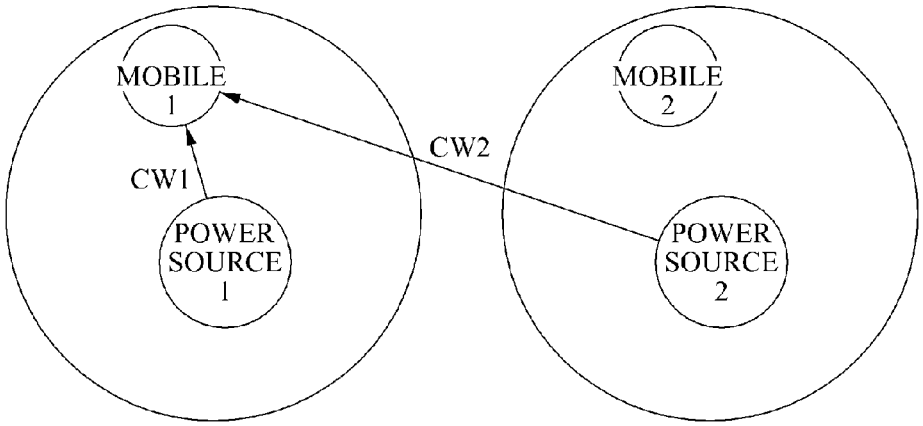


FIG. 9

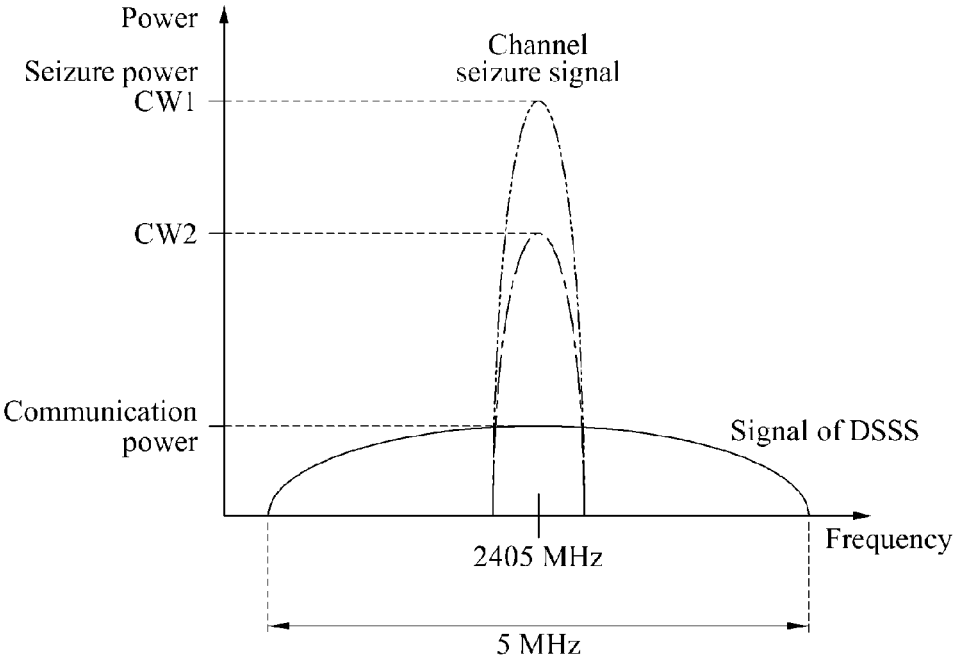

Power
Seizure power
CW1
CW2
Communication
power
Channel
seizure signal
Signal of DSSS
Frequency
2405 MHz
5 MHz

FIG. 10

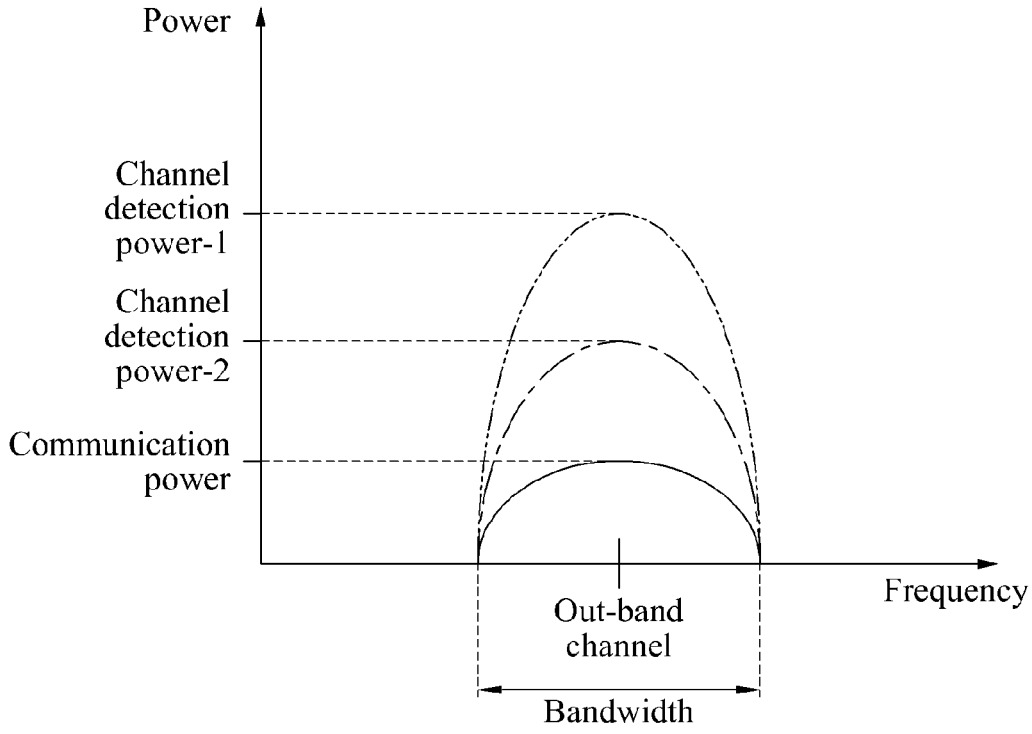

Power
Channel detection power-1
Channel detection power-2
Communication power
Frequency
Out-band channel
Bandwidth

**FIG. 11**

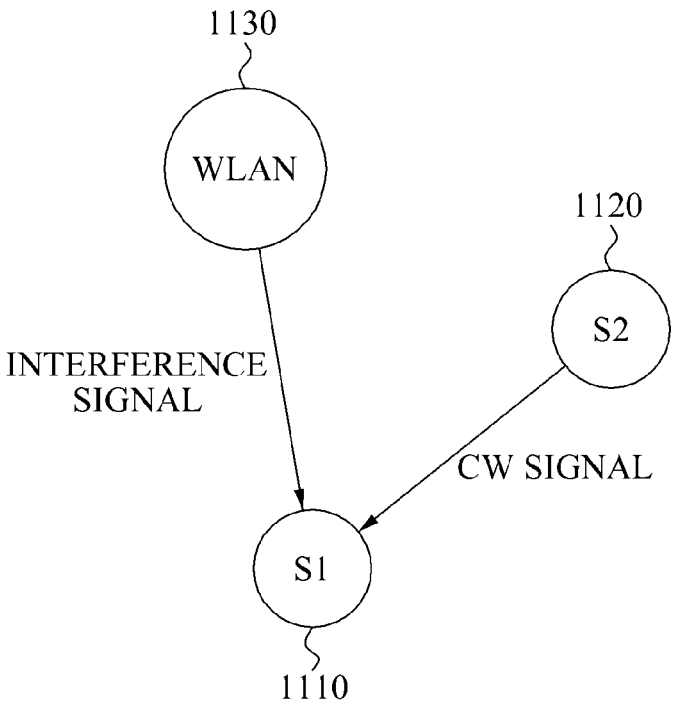


FIG. 12

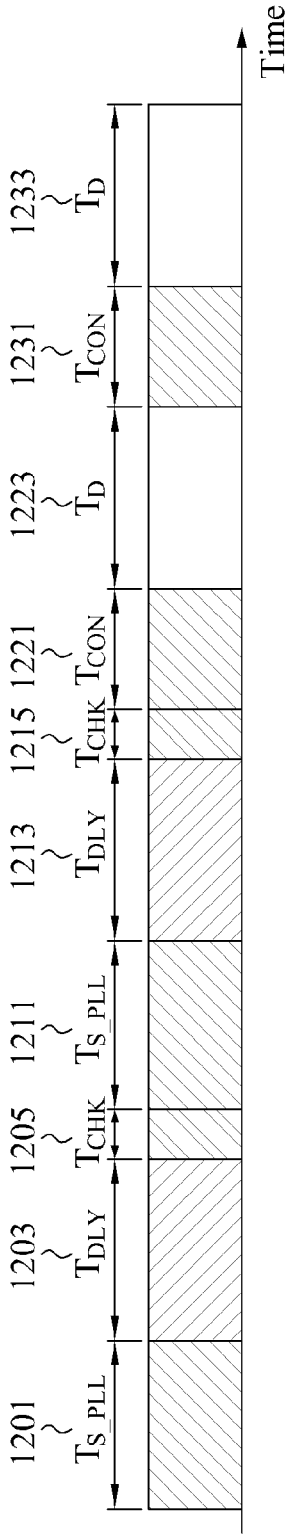

Time
1201
$T_{S_PLL}$
1203
$T_{DLY}$
1205
$T_{CHK}$
1211
$T_{S_PLL}$
1213
$T_{DLY}$
1215
$T_{CHK}$
1221
$T_{CON}$
1223
$T_D$
1231
$T_{CON}$
1233
$T_D$

FIG. 13

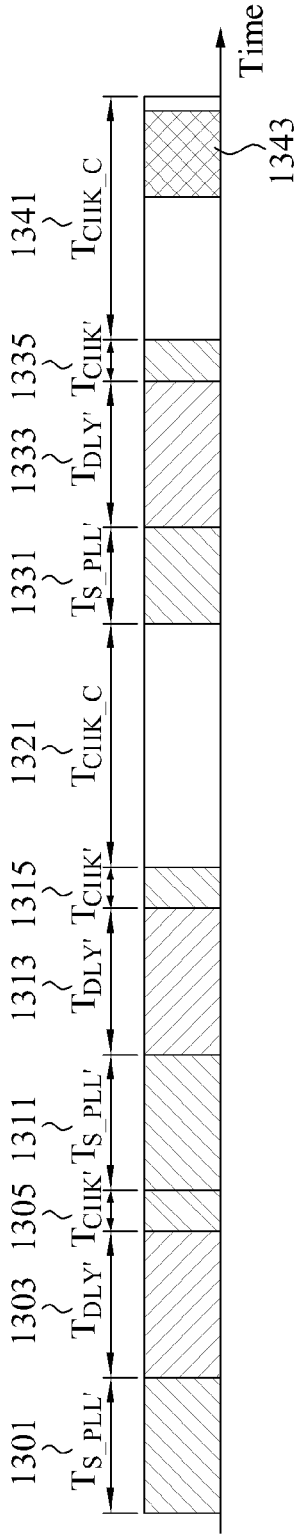

Time
1343
1341
$T_{CIIK_C}$
1335
$T_{CIIK'}$
1333
$T_{DLY'}$
1331
$T_{S_PLL'}$
1321
$T_{CIIK_C}$
1315
$T_{CIIK'}$
1313
$T_{DLY'}$
1311
$T_{S_PLL'}$
1305
$T_{CIIK'}$
1303
$T_{DLY'}$
1301
$T_{S_PLL'}$

FIG. 14

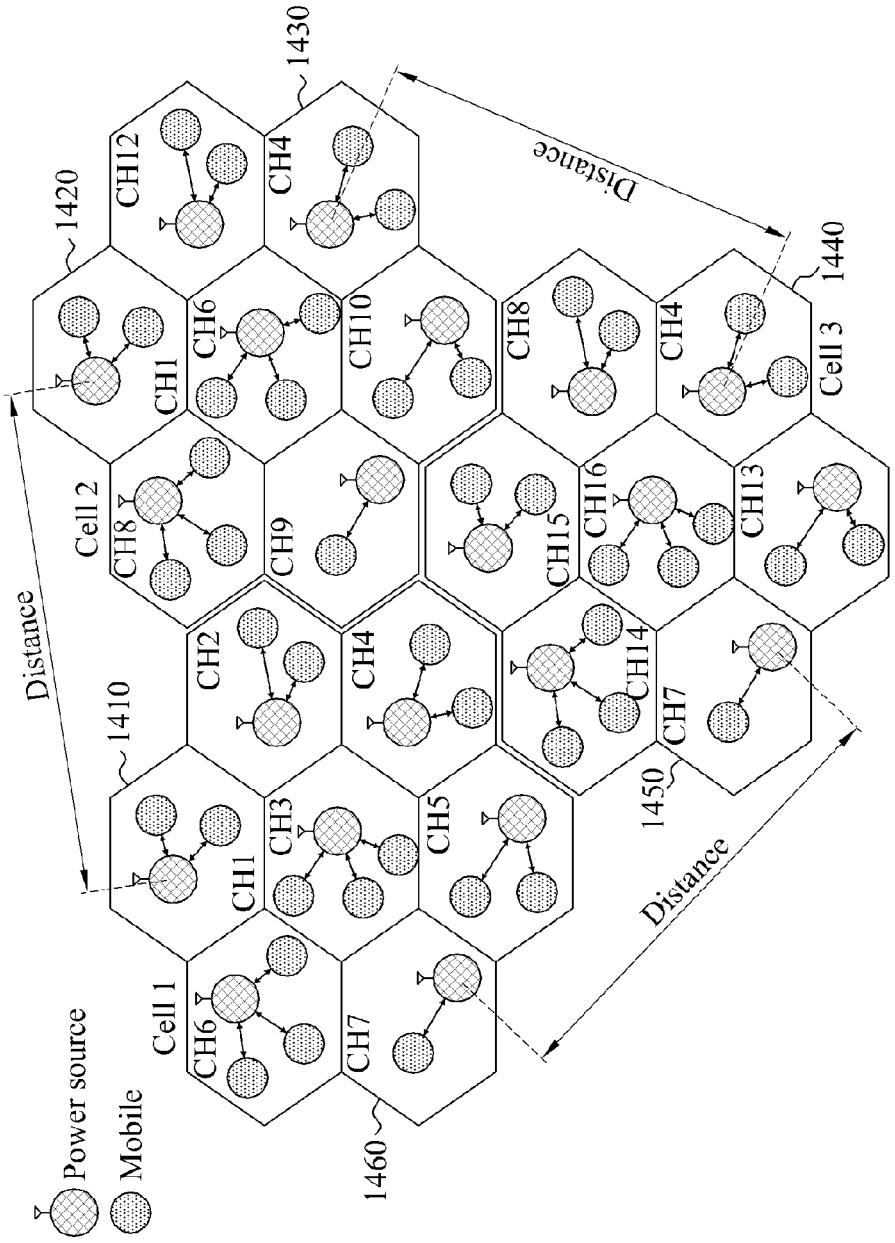

Power source
Mobile
Cell 1
Cell 2
Cell 3
CH1
CH2
CH3
CH4
CH5
CH6
CH7
CH8
CH9
CH10
CH12
CH13
CH14
CH15
CH16
1410
1420
1430
1440
1450
1460
Distance
Distance

FIG. 15

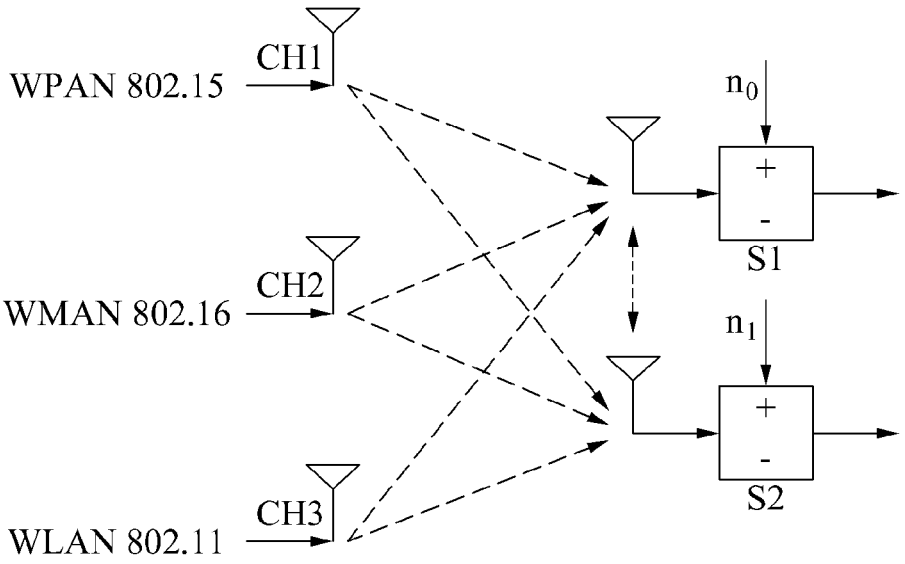


FIG. 16

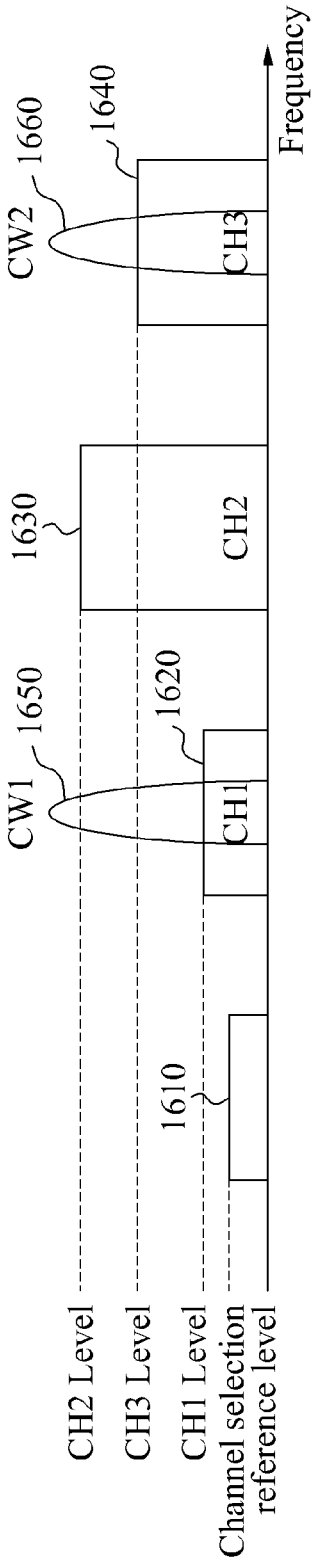

Frequency
CW2
1660
1640
CH3
1630
CH2
CW1
1650
1620
CH1
1610
CH2 Level
CH3 Level
CH1 Level
Channel selection reference level

FIG. 17

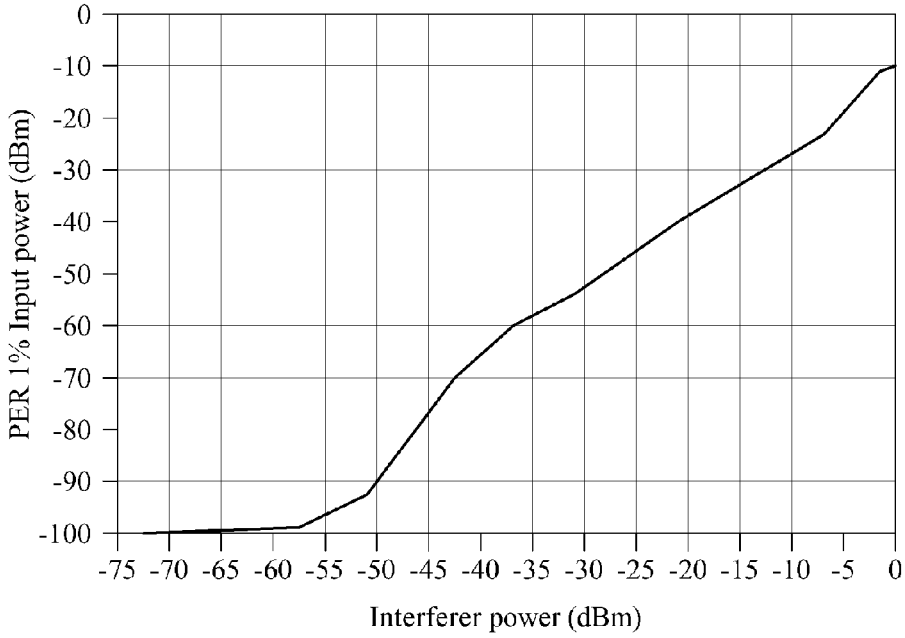

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
PER 1% Input power (dBm)
-75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0
Interferer power (dBm)

FIG. 18

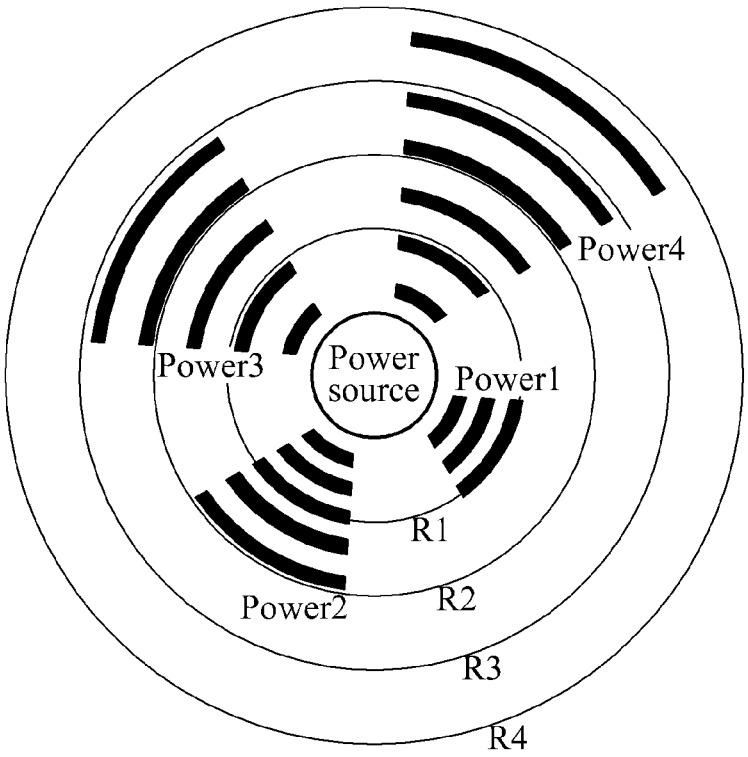


FIG. 19

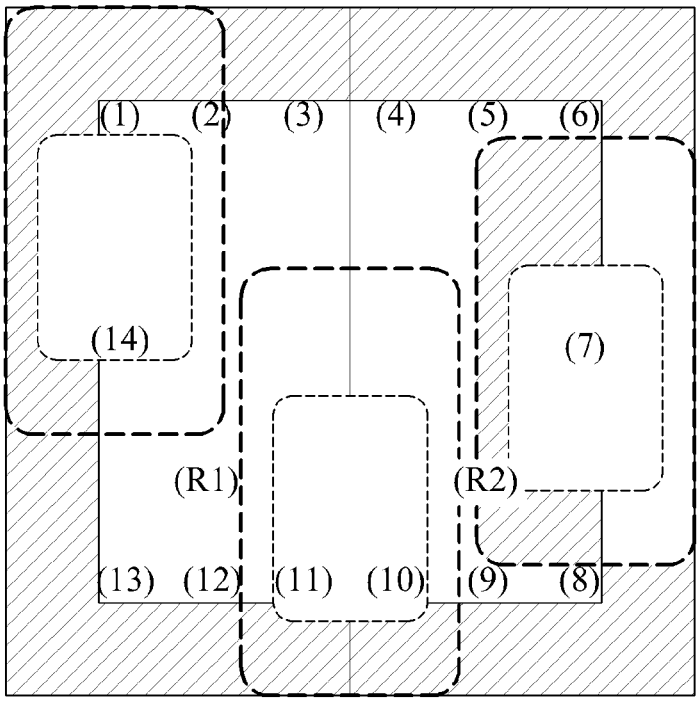


**FIG. 20**

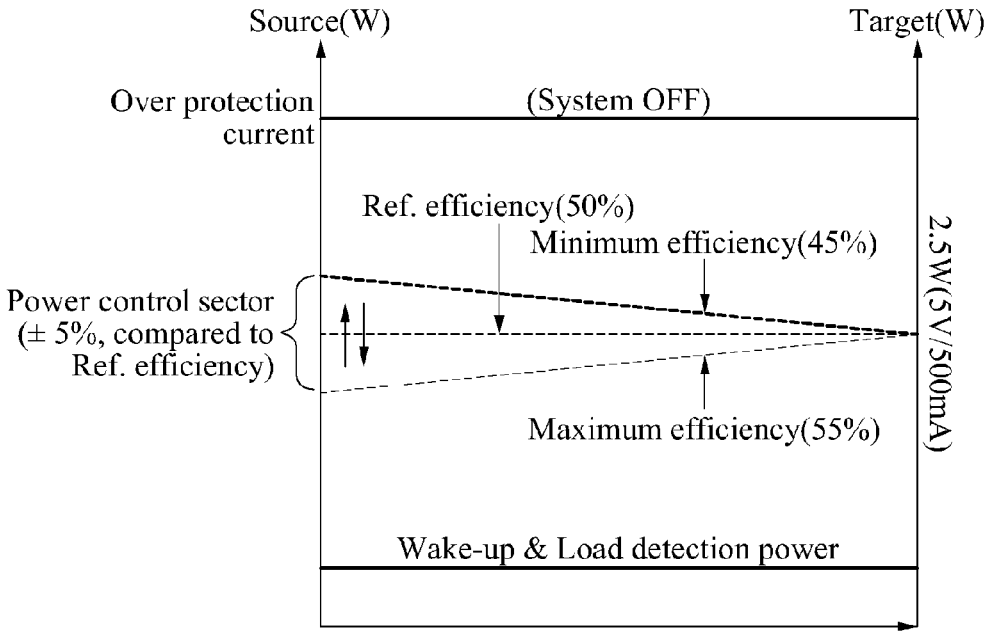

Source(W)
Target(W)
Over protection current
(System OFF)
Ref. efficiency(50%)
Minimum efficiency(45%)
Power control sector (± 5%, compared to Ref. efficiency)
2.5W(5V/500mA)
Maximum efficiency(55%)
Wake-up & Load detection power

FIG. 21

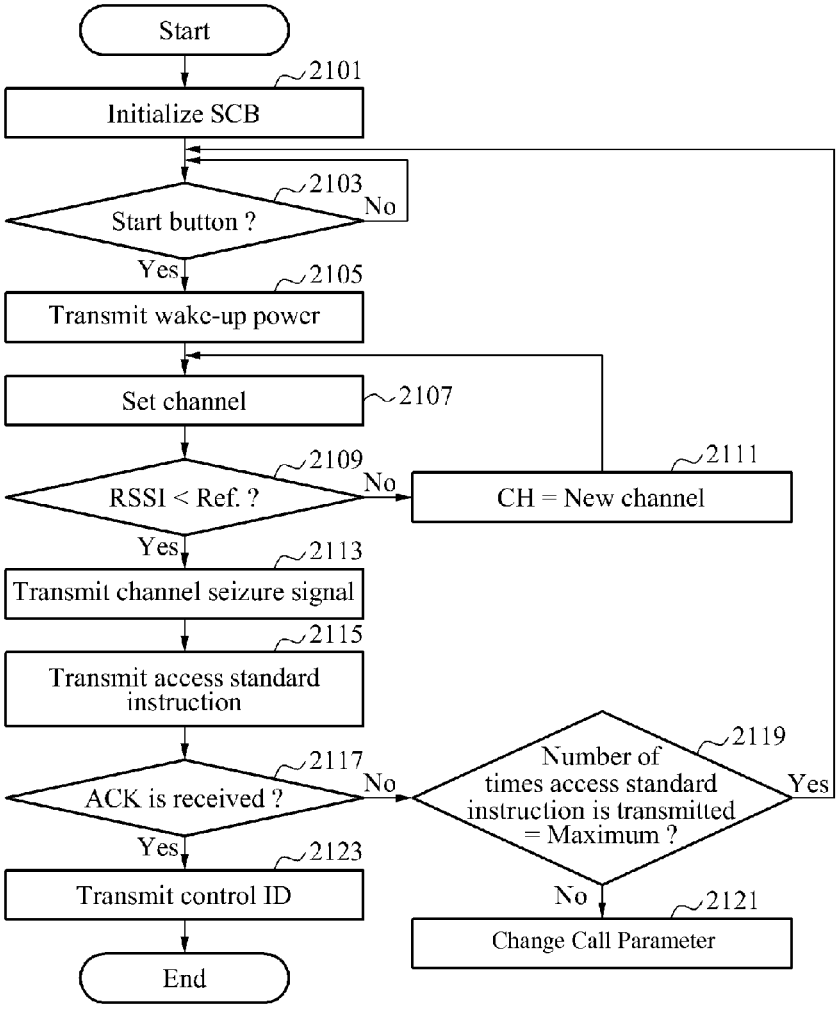

Start
2101
Initialize SCB
2103
Start button ?
No
Yes
2105
Transmit wake-up power
Set channel
2107
2109
RSSI < Ref. ?
No
2111
CH = New channel
Yes
2113
Transmit channel seizure signal
2115
Transmit access standard instruction
2117
ACK is received ?
No
2119
Number of times access standard instruction is transmitted = Maximum ?
Yes
Yes
2123
Transmit control ID
No
2121
Change Call Parameter
End

FIG. 22

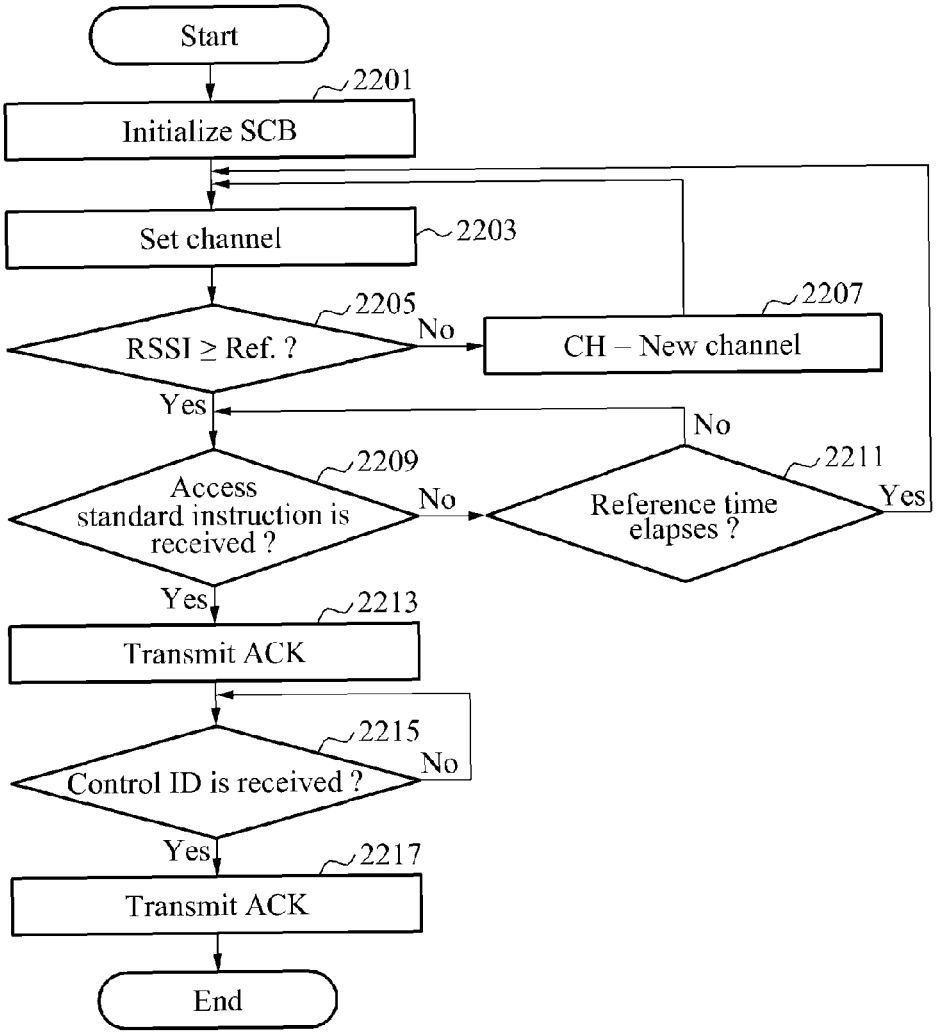

Start
2201
Initialize SCB
Set channel
2203
2205
RSSI ≥ Ref. ?
No
2207
CH – New channel
Yes
No
2209
Access standard instruction is received ?
No
2211
Reference time elapses ?
Yes
Yes
2213
Transmit ACK
2215
Control ID is received ?
No
Yes
2217
Transmit ACK
End

FIG. 23

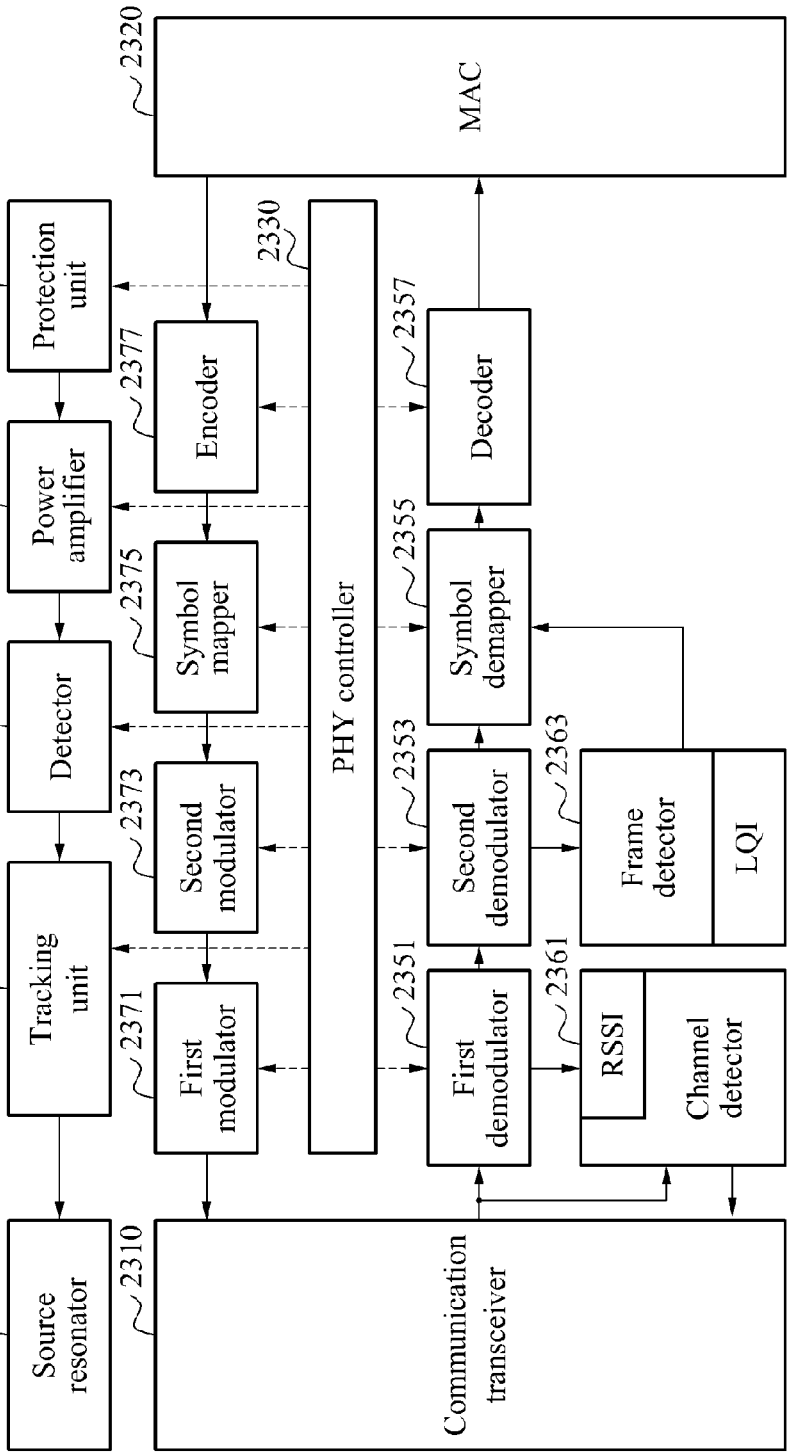

2320
MAC
2330
PHY controller
2387
Protection unit
2385
Power amplifier
2383
Detector
2381
Tracking unit
2340
Source resonator
2377
Encoder
2375
Symbol mapper
2373
Second modulator
2371
First modulator
2310
Communication transceiver
2357
Decoder
2355
Symbol demapper
2353
Second demodulator
2351
First demodulator
2363
Frame detector
LQI
2361
RSSI
Channel detector

FIG. 24A

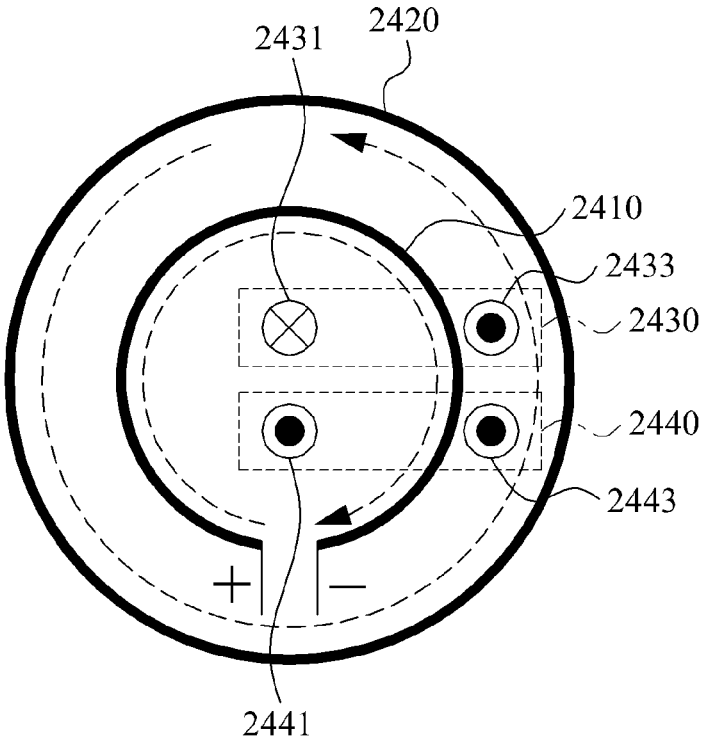


FIG. 24B

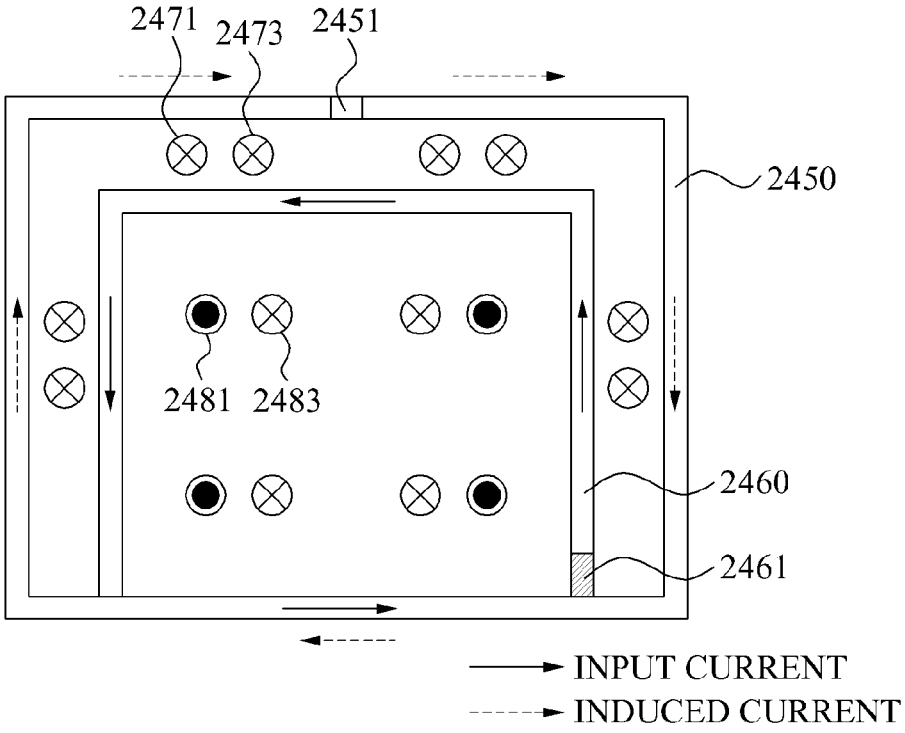

2471
2473
2451
2450
2481
2483
2460
2461
INPUT CURRENT
INDUCED CURRENT

FIG. 25A

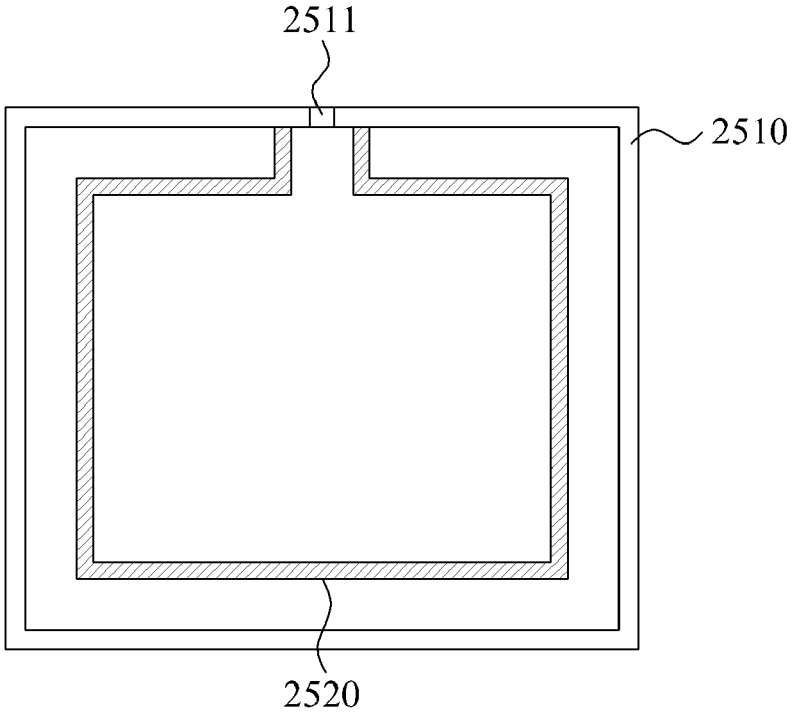


FIG. 25B

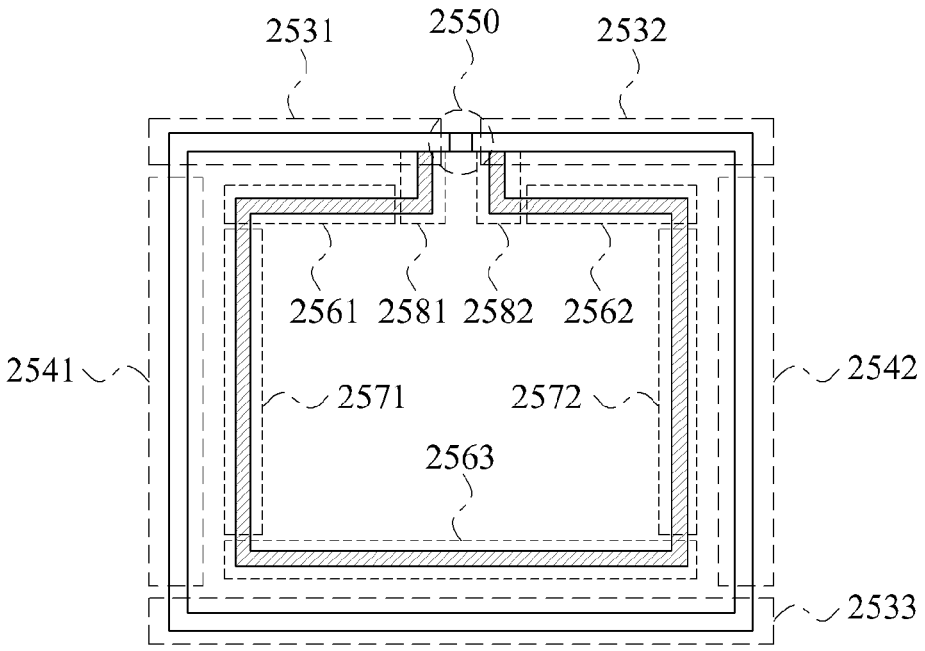

2531
2550
2532
2561
2581
2582
2562
2541
2542
2571
2572
2563
2533

FIG. 26A

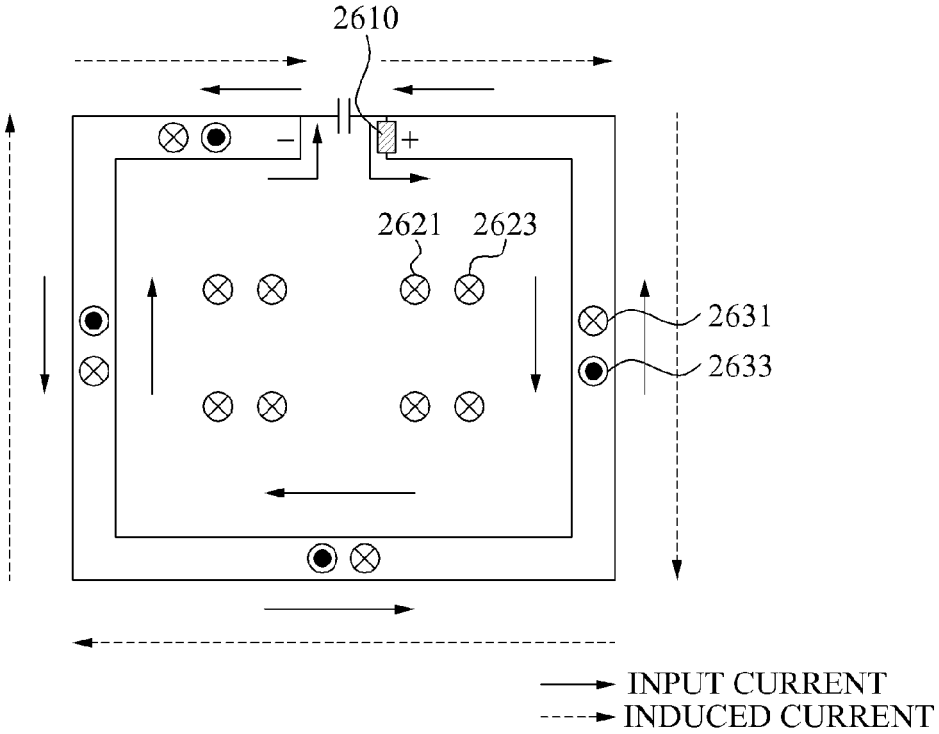


**FIG. 26B**

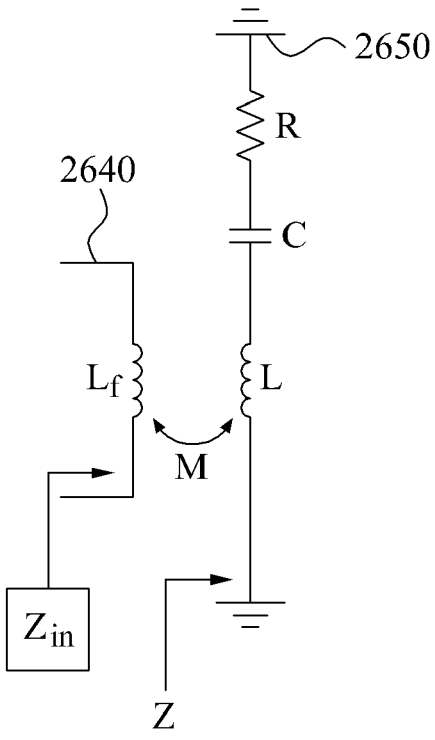
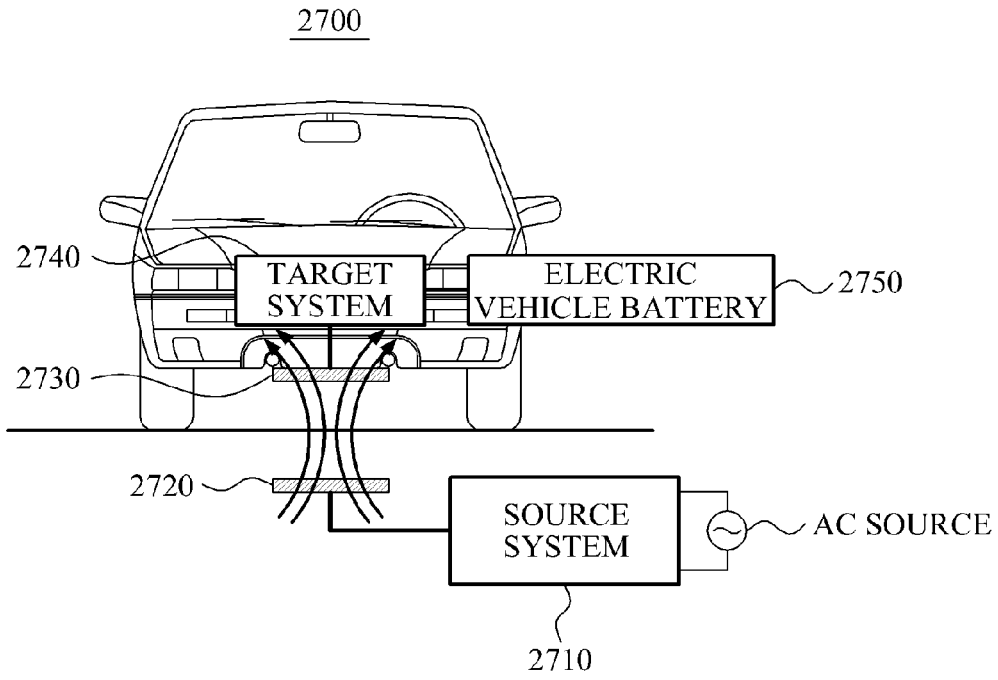


**FIG. 27**


2700
2740
TARGET SYSTEM
ELECTRIC VEHICLE BATTERY
2750
2730
2720
SOURCE SYSTEM
AC SOURCE
2710

# COMMUNICATION APPARATUS AND COMMUNICATION METHOD IN WIRELESS POWER TRANSMISSION SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit under 35 U.S.C. §119 (a) of Korean Patent Application No. 10-2011-0089396, filed on Sep. 5, 2011, and Korean Patent Application No. 10-2011-0110531, filed on Oct. 27, 2011, in the Korean Intellectual Property Office, the entire disclosures of which are each incorporated herein by reference for all purposes.

## BACKGROUND

1. Field

The following description relates to an apparatus and method for performing communication in a wireless power transmission system.

2. Description of Related Art

Research on wireless power transmission have been started to overcome the increasing inconvenience of wired power supplies, and the limited capacity of conventional batteries, due to the increasing number of various electronic devices including electric vehicles and mobile devices. One wireless power transmission technology uses resonance characteristics of radio frequency (RF) devices.

For example, a wireless power transmission system using resonance characteristics may include a source device configured to supply a power, and a target device configured to receive supplied power. To efficiently transmit power from the source device to the target device, the source device and the target device may need to exchange information on a state of the source device, and information on a state of the target device, with each other. In other words, there is a demand to perform communication between the source device and the target device.

## SUMMARY

In one general aspect, there is provided a communication apparatus in a wireless power transmission system, the communication apparatus including a channel search unit configured to search for communication channels other than a channel used in wireless power transmission, and measure state information of the communication channels. The communication apparatus further includes a channel determining unit configured to determine a communication channel available for communication with a target device based on the measured state information. The communication apparatus further includes a communication unit configured to transmit an access instruction to the target device using the determined communication channel. The communication apparatus further includes a controller configured to determine whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access instruction is received.

The communication apparatus may be configured to detect the target device in a wireless power transmission region of the communication apparatus.

The channel search unit may include a channel measuring unit configured to measure intensities of interference signals of the respective communication channels.

The channel measuring unit may be further configured to measure the intensities for a predetermined period of time.



The channel determining unit may be further configured to determine a communication channel including an intensity of an interference signal that is less than or equal to a predetermined value, among the measured intensities, to be the communication channel available for communication with the target device.

The channel determining unit may be further configured to determine a communication channel including an intensity of an interference signal that is lowest in value, among the measured intensities, to be the communication channel available for communication with the target device if each of the intensities are greater than or equal to a channel selection reference level.

The communication unit may be further configured to transmit a channel seizure signal to the target device, the channel seizure signal including a predetermined intensity.

The channel seizure signal may be a continuous wave (CW) signal including a predetermined intensity and a power greater than a communication signal of a direct-sequence spread spectrum (DSSS).

The controller may be further configured to assign a control identifier (ID) to the target device if the response signal is received.

The communication unit may be further configured to transmit a signal to request information on a power required by the target device using a communication frequency of the determined communication channel.

The controller may be further configured to determine an amount of a wireless power to be transmitted by the communication apparatus based on the information regarding the power required by the target device. The controller may be further configured to control a wireless power output from the communication apparatus based on the determined amount of the wireless power.

The channel search unit may be further configured to search for the communication channels based on a search table set based on a type of the communication apparatus, or a unique ID assigned to the communication apparatus.

The controller may be further configured to control the channel search unit to search for the communication channels, regardless of whether the target device is waked up.

The controller may be further configured to determine whether the communication apparatus is accessed by the target device based on information on a power of a communication output of the communication apparatus in the determined communication channel, and information on a power of the communication output received by the target device.

The controller may be further configured to control the channel search unit to search for the communication channels based on a channel search start command if the communication apparatus is not accessed by the target device. The controller may be further configured to control the channel search unit to search for the communication channels based on an amount of a change in a current output from the communication apparatus if the communication apparatus is accessed by the target device.

The controller may be further configured to determine a difference between a wireless power transmitted by the communication apparatus and a power transferred to a load of the target device. The controller may be further configured to determine whether the target device incorrectly accesses the communication apparatus based on the determined difference.

The controller may be further configured to determine a difference between a time in which an amount of a wireless power transmitted by the communication apparatus is changed to a predetermined value, and a time in which an

amount of a power transferred to a load of the target device is changed. The controller may be further configured to determine whether the target device incorrectly accesses the communication apparatus based on the determined difference.

The controller may be further configured to determine a power of a communication output in the determined communication channel based on a table to which an intensity of an interference signal in the determined communication channel, and a power of an output signal required to transmit data within a predetermined error range, are mapped.

The controller may be further configured to determine a time required to measure intensities of interference signals of the respective communication channels.

The controller may be further configured to determine to change the determined communication channel to another communication channel if an error in the determined communication channel between the communication apparatus and the target device is greater than a predetermined value, or if an intensity of an interference signal of the determined communication channel is greater than a predetermined value. The controller may be further configured to transmit a channel change request instruction to the target device.

In another general aspect, there is provided a communication apparatus in a wireless power transmission system, the communication apparatus including a channel search unit configured to search for communication channels other than a channel used in wireless power transmission, and measure state information of the communication channels. The communication apparatus further includes a channel determining unit configured to determine a communication channel available for communication with a source device based on the measured state information. The communication apparatus further includes a controller configured to determine whether to communicate with the source device using the determined communication channel based on whether an access instruction is received from the source device using the determined communication channel.

The controller may be further configured to determine whether the access instruction is received from the source device using the determined communication channel within a reference time.

The communication apparatus may further include a communication unit configured to transmit, to the source device, a response signal corresponding to the access instruction if the access instruction is received within the reference time.

The communication unit may be further configured to receive, from the source device, a control ID assigned to the communication apparatus and that corresponds to the response signal.

The channel search unit may be further configured to search for another communication channel, and measure state information of the other communication channel, if the access instruction is not received within the reference time.

The channel search unit may be further configured to measure intensities of channel seizure signals of the respective communication channels that are transmitted by the source device. The channel determining unit may be further configured to determine a communication channel including an intensity of a channel seizure signal that is greater than a predetermined value, among the intensities, to be the communication channel available for communication with the source device.

The communication apparatus may be configured to receive channel seizure signals from source devices. The controller may be further configured to select one of the source devices using a communication channel including an intensity of a channel seizure signal that is greatest in value, from among the source devices, and determine to receive a wireless power from the selected one of the source devices.

The channel determining unit may be further configured to determine the communication channel used by the selected one of the source devices to be a communication channel available for communication with the selected one of the source devices.

The channel search unit may be further configured to search for the communication channels based on a search table set based on a type of the communication apparatus, or a unique ID assigned to the communication apparatus.

The communication apparatus may further include a direct current (DC)-to-DC (DC/DC) converter. The communication apparatus may further include a load. The controller may be further configured to determine a power required by the communication apparatus based on a power measured at an input end of the DC/DC converter, a power measured at an output end of the DC/DC converter, and a power transferred to the load.

In still another general aspect, there is provided a communication method in a wireless power transmission system, the communication method including searching for communication channels other than a channel used in wireless power transmission. The communication method further includes measuring state information of the communication channels. The communication method further includes determining a communication channel available for communication with a target device based on the measured state information. The communication method further includes transmitting an access instruction to the target device using the determined communication channel. The communication method further includes determining whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access instruction is received.

The communication method may further include transmitting a channel seizure signal to the target device, the channel seizure signal including a predetermined intensity.

The measuring of the state information may include measuring intensities of interference signals of the respective communication channels.

The determining of the communication channel may include determining a communication channel including an intensity of an interference signal that is less than or equal to a predetermined value, among the measured intensities, to be the communication channel available for communication with the target device.

In yet another general aspect, there is provided a communication method in a wireless power transmission system, the communication method including searching for communication channels other than a channel used in wireless power transmission. The communication method further includes measuring state information of the communication channels. The communication method further includes determining a communication channel available for communication with a source device based on the measured state information. The communication method further includes determining whether to communicate with the source device using the determined communication channel based on whether an access instruction is received from the source device using the determined communication channel.

Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an example of a wireless power transmission system.

FIG. **2** is a diagram illustrating an example of an environment in which a wireless power transmission system is exposed to different wireless communication schemes.

FIG. **3** is a diagram illustrating an example of an environment in which wireless power transmission systems perform communication using the same channel.

FIG. **4** is a diagram illustrating an example of an operating mode of a communication apparatus in a wireless power transmission system.

FIG. **5** is a block diagram illustrating an example of a communication apparatus in a wireless power transmission system.

FIG. **6** is a block diagram illustrating another example of a communication apparatus in a wireless power transmission system.

FIG. **7** is a diagram illustrating an example of communication channels that may be used in a wireless power transmission system.

FIG. **8** is a diagram illustrating an example of a method of a target device determining a communication channel based on a continuous wave (CW) signal in a wireless power transmission system.

FIG. **9** is a graph illustrating examples of powers of CW signals received by a target device in a wireless power transmission system.

FIG. **10** is a graph illustrating examples of powers of communication channel signals received by a target device in a wireless power transmission system.

FIG. **11** is a diagram illustrating an example of an interference signal influencing a source device in a wireless power transmission system.

FIG. **12** is a graph illustrating an example of a timing in which a source device determines a communication channel in a wireless power transmission system.

FIG. **13** is a graph illustrating an example of a timing in which a target device determines a communication channel in a wireless power transmission system.

FIG. **14** is a diagram illustrating an example of wireless power transmission systems placed in a cell unit.

FIG. **15** is a diagram illustrating an example of communication networks influencing communication channels of source devices in a wireless power transmission system.

FIG. **16** is a graph illustrating an example of intensities of signals detected from communication channels in a wireless power transmission system.

FIG. **17** is a graph illustrating an example of a relationship between a power of a signal interfering with a communication channel of a source device, and an input power in the communication channel, in a wireless power transmission system.

FIG. **18** is a diagram illustrating an example of a communication distance based on an adjustment of a power output from a power source device in a wireless power transmission system.

FIG. **19** is a diagram illustrating an example of a position of a target device in a wireless power transmission system.

FIG. **20** is a graph illustrating an example of a power transmission efficiency based on a position of a target device in a wireless power transmission system.

FIG. **21** is a flowchart illustrating an example of a communication method in a wireless power transmission system.

FIG. **22** is a flowchart illustrating another example of a communication method in a wireless power transmission system.

FIG. **23** is a block diagram illustrating still another example of a communication apparatus in a wireless power transmission system.

FIGS. **24**A through **24**B are diagrams illustrating examples of a distribution of a magnetic field in a feeder and a resonator of a wireless power transmission system.

FIGS. **25**A and **25**B are diagrams illustrating an example of a wireless power transmitter.

FIG. **26**A is a diagram illustrating an example of a distribution of a magnetic field inside a resonator produced by feeding of a feeding unit.

FIG. **26**B is a diagram illustrating examples of equivalent circuits of a feeding unit and a resonator.

FIG. **27** is a diagram illustrating an example of an electric vehicle charging system.

Throughout the drawings and the detailed description, unless otherwise described, the same drawing reference numerals will be understood to refer to the same elements, features, and structures. The relative size and depiction of these elements may be exaggerated for clarity, illustration, and convenience.

## DETAILED DESCRIPTION

The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. Accordingly, various changes, modifications, and equivalents of the systems, apparatuses, and/or methods described herein will be suggested to those of ordinary skill in the art. The progression of processing steps and/or operations described is an example; however, the sequence of steps and/or operations is not limited to that set forth herein and may be changed as is known in the art, with the exception of steps and/or operations necessarily occurring in a certain order. Also, description of well-known functions and constructions may be omitted for increased clarity and conciseness.

A scheme of performing communication between a source device and a target device includes an in-band communication scheme and an out-band communication scheme. The in-band communication scheme refers to communication performed between the source device and the target device in the same frequency band as used for power transmission. The out-band communication scheme refers to communication performed between the source device and the target device in a separate frequency band than used for power transmission.

FIG. **1** illustrates an example of a wireless power transmission system. The wireless power transmission system includes a source **110** and a target **120**. The source **110** refers to a device configured to supply a wireless power, and may include all electronic devices enabling power supply, for example, a pad, a terminal, a television (TV), and/or other electronic devices known to one of ordinary skill in the art. The target **120** refers to a device configured to receive the supplied wireless power, and may include all electronic devices requiring power, for example, a terminal, a TV, a vehicle, a washing machine, a radio, an electric light, and/or other electronic devices known to one of ordinary skill in the art.

The source **110** includes a variable switching mode power supply (SMPS) **111**, a power amplifier **112**, a matching network **113**, a controller **114**, a communication unit **115**, and a power detector **116**. The variable SMPS **111** switches alternating current (AC) voltage in a band of tens of hertz (Hz) output from a power supply to generate direct current (DC) voltage. The variable SMPS **111** may output the DC voltage of a predetermined level, or may adjust an output level of the DC voltage based on a control of the controller **114**.

A power detector **116** detects an output current and an output voltage of the variable SMPS **111**, and transfers, to the

controller **114**, information on the detected current and the detected voltage. Additionally, the power detector **116** may detect an input current and an input voltage of the power amplifier **112**.

The power amplifier **112** converts the DC voltage to an AC voltage based on a switching pulse signal in a band of a few megahertz (MHz) to tens of MHz to generate a power. For example, the power amplifier **112** may convert the DC voltage supplied to the power amplifier **112** to the AC voltage based on a reference resonance frequency $F_{Ref}$, and may generate a communication power used for communication, and/or a charging power used to charge. The communication power and the charging power may be used in target devices.

The communication power may refer to a low power of 0.1 milliwatt (mW) to 1 mW. The charging power may refer to a high power of 1 mW to 200 W that is consumed in a device load of a target device. In various examples described herein, the term "charging" may refer to supplying power to a unit or element that is configured to charge power. Additionally, the term "charging" may refer to supplying power to a unit or element that is configured to consume power. The units or elements may include, for example, batteries, displays, sound output circuits, main processors, various sensors, and or other units or elements known to one of ordinary skill in the art.

Also, the term "reference resonance frequency" may refer to a resonance frequency used by the source **110**. Additionally, the term "tracking frequency" may refer to a resonance frequency adjusted by a preset scheme.

The controller **114** detects a reflected wave of the communication power and/or the charging power, and may detect mismatching that may occur between a target resonator **133** and a source resonator **131** based on the detected reflected wave. To detect the mismatching, for example, the controller **114** may detect an envelope of the reflected wave, a power amount of the reflected wave, and/or other values known to one of ordinary skill in the art.

The matching network **113** compensates for impedance mismatching between the source resonator **131** and the target resonator **133** to be optimal matching, under the control of the controller **114**. The matching network **113** may be connected through a switch, including a combination of a capacitor and an inductor, under the control of the controller **114**.

The controller **114** determines a voltage standing wave ratio (VSWR) based on a voltage level of the reflected wave, and an output voltage of the source resonator **131** or the power amplifier **112**. For example, if the VSWR is less than a predetermined value, the controller **114** determines that mismatching is detected.

In this example, the controller **114** determines a power transmission efficiency for each of N tracking frequencies, determines a tracking frequency $F_{Best}$ with the best power transmission efficiency among the N tracking frequencies, and adjusts the reference resonance frequency $F_{Ref}$ to the tracking frequency $F_{Best}$. In various examples, the N tracking frequencies may be set in advance.

The controller **114** adjusts a frequency of the switching pulse signal. Under the control of the controller **114**, the frequency of the switching pulse signal is determined. For example, by controlling the power amplifier **112**, the controller **114** may generate a modulation signal to be transmitted to the target **120**. In other words, the communication unit **115** may transmit a variety of data **140** to the target **120** using the in-band communication. The controller **114** may detect a reflected wave, and may demodulate a signal received from the target **120** through an envelope of the detected reflected wave.

The controller **114** may generate the modulation signal for the in-band communication based on various ways. For example, the controller **114** may generate the modulation signal by turning on and off the switching pulse signal, by performing delta-sigma modulation, and/or other types of methods known to one of ordinary skill in the art. Additionally, the controller **114** may generate a pulse-width modulation (PWM) signal with a predetermined envelope.

The communication unit **115** may perform out-band communication employing a communication channel. The communication unit **115** may include a communication module, such as, for example, one configured to process ZigBee, Bluetooth, and/or other communication protocols known to one of ordinary skill in the art. The communication unit **115** may transmit the data **140** to the target **120** through the out-band communication.

The source resonator **131** transfers an electromagnetic energy **130** to the target resonator **133**. For example, the source resonator **131** may transfer the communication power and/or the charging power to the target **120** based on magnetic coupling with the target resonator **133**.

The target **120** includes a matching network **121**, a rectification unit **122**, a DC-to-DC (DC/DC) converter **123**, a communication unit **124**, and a controller **125**, and a power detector **127**. The target resonator **133** receives the electromagnetic energy **130** from the source resonator **131**. For example, the target resonator **133** may receive the communication power and/or charging power from the source **110** based on the magnetic coupling with the source resonator **131**. Additionally, the target resonator **133** may receive the data **140** from the source **110** using the in-band communication.

The matching network **121** matches an input impedance viewed from the source **110** to an output impedance viewed from a load of the target **120**. The matching network **121** may be configured with a combination of a capacitor and an inductor.

The rectification unit **122** rectifies an AC voltage to generate a DC voltage. The AC voltage may be received from the target resonator **133**.

The DC/DC converter **123** adjusts a level of the DC voltage output from the rectification unit **122**, based on a capacity required by the load. For example, the DC/DC converter **123** may adjust the level of the DC voltage output from the rectification unit **122** from 3 volts (V) to 10 V.

The power detector **127** detects a voltage of an input terminal **126** of the DC/DC converter **123**, and a current and a voltage of an output terminal of the DC/DC converter **123**. The detected voltage of the input terminal **126** is used to determine a transmission efficiency of the power received from the source **110**. Additionally, the detected current and the detected voltage of the output terminal is used by the controller **125** to determine an amount of a power transferred to the load. The controller **114** of the source **110** determines an amount of a power to be transmitted by the source **110** based on a power required by the load and the power transferred to the load. If the power of the output terminal is transferred to the source **110** using the communication unit **124**, the source **110** may determine the amount of the power to be transmitted.

The communication unit **124** may perform in-band communication to transmit and receive data based on a resonance frequency. During the in-band communication, the controller **125** detect a signal between the target resonator **133** and the rectification unit **122**, or detect an output signal of the rectification unit **122**, to demodulate the detected signal. In other words, the controller **125** may demodulate a message received using the in-band communication. Additionally, the

controller **125** may adjust an impedance of the target resonator **133** using the matching network **121** to modulate a signal to be transmitted to the source **110**. For example, the controller **125** may increase the impedance of the target resonator **133** so that a reflected wave may be detected by the controller **114** of the source **110**. Depending on whether the reflected wave is detected, the controller **114** may detect a binary number, for example, "0" or "1".

The communication unit **124** may transmit a response message to the communication unit **115** of the source **110**. For example, the response message may include a type of a corresponding target (e.g., the target **120**), information about a manufacturer of a corresponding target, a model name of a corresponding target, a battery type of a corresponding target, a scheme of charging a corresponding target, an impedance value of a load of a corresponding target, information on characteristics of a target resonator (e.g., the target resonator **133**) of a corresponding target, information on a frequency band used by a corresponding target, an amount of a power consumed by a corresponding target, an identifier (ID) of a corresponding target, information on version or standard of a corresponding target, and/or other information known to one of ordinary skill in the art.

The communication unit **124** may perform out-band communication using a communication channel. For example, the communication unit **124** may include a communication module, such as, for example, one configured to process ZigBee, Bluetooth, and/or other communication protocols known to one of ordinary skill in the art. The communication unit **124** may transmit and receive the data **140** to and from the source **110** using the out-band communication.

The communication unit **124** receives a wake-up request message from the source **110**, and the power detector **127** detects an amount of a power received at the target resonator **133**. The communication unit **124** transmits, to the source **110**, information on the detected amount of the power. Information on the detected amount may include, for example, an input voltage value and an input current value of the rectification unit **122**, an output voltage value and an output current value of the rectification unit **122**, an output voltage value and an output current value of the DC/DC converter **123**, and/or other values known to one of ordinary skill in the art.

The controller **114** sets a resonance bandwidth of the source resonator **131**. Based on the setting of the resonance bandwidth of the source resonator **131**, a Q-factor of the source resonator **131** may be determined.

Additionally, the controller **125** sets a resonance bandwidth of the target resonator **133**. Based on the setting of the resonance bandwidth of the target resonator **133**, a Q-factor of the target resonator **133** may be determined. For example, the resonance bandwidth of the source resonator **131** may be set to be wider or narrower than the resonance bandwidth of the target resonator **133**.

The source **110** and the target **120** communicate with each other to share information on the resonance bandwidth of the source resonator **131** and the resonance bandwidth of the target resonator **133**. In an example in which a power desired or required by the target **120** is greater than a reference value, the Q-factor of the source resonator **131** may be set to a value greater than "100". In another example in which the power desired or required by the target **120** is less than the reference value, the Q-factor of the source resonator **131** may be set to a value less than "100".

In a wireless power transmission employing a resonance scheme, the resonance bandwidth is a factor. A Q-factor Qt may consider a change in a distance between the source resonator **131** and the target resonator **133**, a change in a resonance impedance, impedance mismatching, a reflected signal, and/or other values known to one of ordinary skill in the art. In this example, the Q-factor Qt may include an inverse-proportional relationship with the resonance bandwidth, as given in the example of Equation 1.

$$\frac{\Delta f}{f_0} = \frac{1}{Qt} = \Gamma_{S,D} + \frac{1}{BW_S} + \frac{1}{BW_D} \quad \text{[Equation 1]}$$

In Equation 1, $f_0$ denotes a central frequency, $\Delta f$ denotes a bandwidth, $\Gamma_{S,D}$ denotes a reflection loss between the source resonator **131** and the target resonator **133**, $BW_S$ denotes the resonance bandwidth of the source resonator **131**, and $BW_D$ denotes the resonance bandwidth of the target resonator **133**.

An efficiency U of a wireless power transmission may be defined, as given in the example of Equation 2.

$$U = \frac{\kappa}{\sqrt{\Gamma_S \Gamma_D}} = \frac{\omega_0 M}{\sqrt{R_S R_D}} = \frac{\sqrt{Q_S Q_D}}{Q_K} \quad \text{[Equation 2]}$$

In Equation 2, $\kappa$ denotes a coupling coefficient of energy coupling between the source resonator **131** and the target resonator **133**, $\Gamma_S$ denotes a reflection coefficient in the source resonator **131**, $\Gamma_D$ denotes a reflection coefficient in the target resonator **133**, $\omega_0$ denotes a resonance frequency, M denotes a mutual inductance between the source resonator **131** and the target resonator **133**, $R_S$ denotes an impedance of the source resonator **131**, $R_D$ denotes an impedance of the target resonator **133**, $Q_S$ denotes the Q-factor of the source resonator **131**, $Q_D$ denotes the Q-factor of the target resonator **133**, and $Q_K$ denotes a Q-factor of the energy coupling between the source resonator **131** and the target resonator **133**.

Referring to Equation 2, the Q-factors may include high relevance to the efficiency of the wireless power transmission. Accordingly, to increase the efficiency of the wireless power transmission, the Q-factors may be set to high values. However, even if the Q-factors $Q_S$ and $Q_D$ are set to extremely high values, the efficiency of the wireless power transmission may be decreased due to a change in the coupling coefficient $\kappa$, the change in the distance between the source resonator **131** and the target resonator **133**, the change in the resonance impedance, impedance mismatching, and/or other values known to one of ordinary skill in the art.

Additionally, to increase the efficiency of the wireless power transmission, the resonance bandwidth of the source resonator **131**, and the resonance bandwidth of the target resonator **133**, may be set to be excessively narrow. However, in this example, impedance mismatching and/or other issues known to one of ordinary skill in the art may occur due to even a small external effect. Considering the impedance mismatching, Equation 1 may be represented as given in the example of Equation 3.

$$\frac{\Delta f}{f_0} = \frac{\sqrt{VSWR} - 1}{Qt\sqrt{VSWR}} \quad \text{[Equation 3]}$$

In an example in which an unbalanced relationship of a resonance bandwidth, or a bandwidth of an impedance matching frequency, between the source resonator **131** and

the target resonator **133** is maintained, a decrease in efficiency of the wireless power transmission may be prevented due to the change in the coupling coefficient κ, the change in the distance between the source resonator **131** and the target resonator **133**, the change in the resonance impedance, impedance mismatching, and/or other values known to one of ordinary skill in the art. In an example in which the unbalanced relationship of the resonance bandwidth, or the bandwidth of the impedance matching frequency, between the source resonator **131** and the target resonator **133** is maintained, based on Equations 1 and 3, an unbalanced relationship between the Q-factors $Q_S$ and $Q_D$ may also be maintained.

FIG. **2** illustrates an example of an environment in which a wireless power transmission system is exposed to different wireless communication schemes. The wireless power transmission system includes a power source device and a mobile device. The power source device and the mobile device perform wireless communication in the environment enabling the communication in an industrial, scientific, medical (ISM) band. The ISM band may refer to a band of 2.4 gigahertz (GHz). The ISM band may be used in a IEEE 802.11 wireless local area network (WLAN) ("WLAN 802.11"), a IEEE 802.15 wireless personal area network (WPAN) ("WPAN 802.15"), and a IEEE 802.16 wireless metropolitan area network (WMAN) ("WMAN 802.16").

When the power source device and the mobile device communicate with each other in the ISM band, interference of radio waves may be caused by different types of wireless communication apparatuses using the WLAN 802.11, the WPAN 802.15, and/or the WMAN 802.16. Accordingly, a communication error between the power source device and the mobile device may occur, and a communication speed may be decreased. Furthermore, it may be difficult to control the wireless power transmission system. In other words, if different types of wireless electronic devices communicate with each other, frequency interference may occur in the wireless power transmission system.

FIG. **3** illustrates an example of an environment in which wireless power transmission systems perform communication using the same channel. Each of the wireless power transmission systems includes a power source device and a mobile device. For example, when power source devices communicate with mobile devices using the same channel (e.g., a channel CH1), frequency interference may occur. In more detail, in a region in which the channel CH1 is available, the power source devices are spaced apart from each other by a predetermined distance, and share the same channel CH1. If a power source device and/or a mobile device approaches within the predetermined distance, frequency interference may occur between the power source devices, and between the mobile device and another power source device.

FIG. **4** illustrates an example of an operating mode of a communication apparatus in a wireless power transmission system. The communication apparatus includes a source device and a target device. The communication apparatus operates in three modes in the wireless power transmission system. The three modes include, for example, a power standby mode, a power access mode, and a power transfer mode (namely, a power charge mode).

The power standby mode refers to a mode in which a communication channel is not connected between an initialized source device and an initialized target device. For example, when power is supplied, the source device performs basic hardware initialization, reads information from a system configuration block (SCB) of the source device, and initializes system information. The system information may include, for example, a serial number of the source device, a maximum number of target devices accessible to the source device, a power transmission parameter, a communication channel parameter, and/or other information known to one of ordinary skill in the art.

When a wake-up power is received from the source device, that is, when a power required to control a system is supplied to the target device, the target device performs basic hardware initialization. Subsequently, the target device may read a serial number of the target device, a battery type, a power transmission parameter, a communication channel parameter, and/or other information known to one of ordinary skill in the art, from an SCB of the target device, and initializes system information. The SCB may refer to a memory configured to support at least 8 bytes, and a capacity of the SCB may be determined based on an improvement of a function of each of the source device and the target device, a type of the source device, and/or a type of the target device.

In the power standby mode, the source device determines whether a charge command is received at the source device. For example, if a start button is input, the charge command is received. In another example, if a target device located within a predetermined distance from the source device is detected, the charge command is automatically received. The source device further determines states of all channels available for communication. For example, the source device measures a level of a received signal strength indication (RSSI) for each channel, and determines whether each channel is available based on the RSSI.

In the power standby mode, the target device searches for channels available for communication. For example, the target device may measure an RSSI, or a link quality indicator (LQI), of a channel. In this example, if the measured RSSI or the measured LQI is greater than or equal to a predetermined value, the target device determines whether a preset packet is received via the channel within a predetermined period of time. If the measured RSSI or the measured LQI is less than the predetermined value, the target device searches for a next channel.

A channel search mode and a channel selection mode are applied while the power standby mode transitions to the power access mode. For example, when a target device is located within a power transmission distance of the source device, the source device searches for a channel enabling communication with the target device. In this example, the source device is operated in the channel search mode. In the channel selection mode, the source device selects, as a communication channel, a channel satisfying a set condition, from among channels enabling communication with the target device, and shares the selected channel with the target device.

If the charge command is received, the source device is operated in the power access mode. If the source device is already accessed by a target device, the source device may detect a level of a reflected wave. If the level of the reflected wave includes a predefined value, the source device determines that another target device exists, and is operated in the power access mode.

If a target device is detected first, or if the charge command is received, the source device transmits the wake-up power via a power transmission channel. The source device may measure an RSSI or LQI in the communication channel enabling communication with the target. If the RSSI or LQI is measured to be greater than or equal to a reference value, the communication channel is determined to be a currently-used channel, and the source device continues to search for a next channel until a channel with an RSSI or LQI including a value

less than the reference value is found. When the channel is found, the source device may fix the found channel, and transmits an access standard instruction, based on a reference in the found channel. When target devices respond to the access standard instruction, the source device assigns control identifiers (IDs) to the target devices in an order that the target devices respond to the access standard instruction.

When at least one target device is connected to the source device, the source device transmits a wake-up power via the power transmission channel. The source device may transmit an access standard instruction to an additionally detected target using the communication channel already determined. If the additionally detected target device responds to the access standard instruction, the source device may assign control IDs to the target devices in an order that the target devices respond to the access standard instruction.

For example, the source device may assign control IDs "1" to "N" to the target devices in an ascending order. In this example, "N" indicates a maximum number of target devices accessible to the source device. When a low control ID assigned to a target device is empty due to completion of charging of the target device, or separation of the target device from the wireless power transmission system, the source device may assign the low control ID to a new target device accessing the source device. For example, if three target devices are chargeable by the source device, control IDs "1" and "2" are assigned, and a target device with the control ID "1" is separated from the wireless power transmission system, the source device may assign the control ID "1", instead of a control ID "3", to a new target device accessing the source device.

When a control ID is assigned to a target device, the source device is operated in the power transmission mode. The source receives information on a power required by the target device from the target device. The information on the required power may be stored in an SCB of the target device. The power transmission mode may be defined to be set in a period from a point in time in which the source device transmits a power, to a point in time in which a battery of the target device is completely charged and a charge control port of the target device is blocked. In the power transmission mode, the source device may regularly receive information on a state of the target device, a voltage and a current of an input end of the target device, and/or a voltage and a current of an output end of the target device, based on rules defined in advance for each product and for each model. The source device may perform a control operation based on the received information.

An operation of the target device may be reset based on a reset instruction to prevent malfunction of the target device. The malfunction of the target may include, for example, an incorrect access to a source, overheating, abnormality in charging, and/or issues known to one of ordinary skill in the art. In more detail, the target device may include a separate port to perform an appropriate operation if the target is overheated, and/or if the input end and the output end of the target are abnormally-operated. For example, if an abnormality occurs, the target device transmits information on the abnormality, while requesting a state of the source device. The target device may verify a temperature, a charging voltage, and/or a supplied power, regardless of the source device, and may terminate charging through a separate processing path.

In another example, if no response is received from the target device, or if a checksum error in a signal transmitted by the source occurs at least a predetermined number of times, the source device changes a currently used communication channel. In this example, the source device is operated in a channel change mode.

FIG. **5** illustrates an example of a communication apparatus **500** in a wireless power transmission system. The communication apparatus **500** includes a channel search unit **510**, a channel determining unit **520**, a controller **530**, and a communication unit **540**. The communication apparatus **500** of FIG. **5** may correspond to a source device in the wireless power transmission system.

The channel search unit **510** searches for communication channels. The communication channels may be different from a channel used in wireless power transmission. The source device may transmit a power using a wireless power transmission channel, and may transmit and receive data using a communication channel. The communication channels may be channels in an ISM band.

The channel search unit **510** selects an n-th channel, as a first target to be searched for, from among searchable channels. For example, channels may be searched for in a descending order, in an ascending order, or in a random order.

The channel search unit **510** may search for communication channels based on a search table. The search table may be set differently based on a type of the source device or a unique ID assigned to the source device. The channel search unit **510** may search for communication channels in different orders for each type of the source device, as illustrated in the example of Table 1. In an example in which the source device corresponds to a type 1, the channel search unit **510** sequentially searches for 16 channels. In another example in which the source device corresponds to a type 5, the channel search unit **510** sequentially searches for the 16 channels from a channel 2.

TABLE 1

| Search table (16 channels, 1~16) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of source or unique ID assigned to source | Type1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | Type2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 |
| | Type3 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | Type4 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 |
| | Type5 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 |
| | Type6 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Type7 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | Type8 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | Type9 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | Type10 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 |
| | Type11 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 |
| | Type12 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Type13 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Type14 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | Type15 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | Type16 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 |

The channel search unit **510** measures state information of one or more communication channels. The state information may include information on whether the communication channels are used by other source devices and/or different types of communication apparatuses.

For example, the channel search unit **510** includes a channel measuring unit **511**. The channel measuring unit **511** measures intensities of interference signals of the respective communication channels. For example, the channel measuring unit **511** may measure an RSSI or LQI of a communication channel.

The channel determining unit **520** determines a communication channel available for communication with a target device based on the state information of the communication channels. The target device may be detected in a wireless power transmission region of the source device. For example, the channel determining unit **520** determines a communication channel with little interference by neighboring devices to be the communication channel available for communication with the target device. The channel determining unit **520** may determine a communication channel including an intensity of an interference signal that is less than or equal to a predetermined reference value, among the measured intensities, to be the communication channel available for communication with the target device. For example, the channel determining unit **520** may determine a communication channel with a minimum RSSI to be the communication channel available for communication with the target device.

The communication unit **540** transmits a channel seizure signal and an access standard instruction to the target device based on a communication frequency of the determined communication channel. The channel seizure signal may include a predetermined intensity. The channel seizure signal may be a continuous wave (CW) signal including the predetermined intensity and a power greater than a communication signal of a direct-sequence spread spectrum (DSSS). The channel seizure signal may be modulated based on a predetermined modulation scheme.

The access standard instruction may include information used for compatibility between the source device and the target device. The access standard instruction may include a call argument and a call parameter used to identify target devices. For example, if the same identifying parameter as a call parameter is included in the target device, the target device transmits, to the source device, a response signal.

The controller **530** determines whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access standard instruction is received. For example, if the response signal is received from the target device, the controller **530** determines to communicate with the target device using the determined communication channel. In response to the response signal, the controller **530** assigns a control ID to the target device.

The communication unit **540** receives, from the target device, a response signal indicating that the control ID is assigned to the target device. If the control ID is assigned to the target device, the communication unit **540** transmits a signal requesting information on a power required by the target device, using the communication frequency of the determined communication channel. The communication unit **540** receives the information on the power required by the target device from the target device.

The controller **530** determines an amount of a wireless power to be transmitted by the source device based on the information on the power required by the target device. Additionally, the controller **530** controls an amount of a power in the source device so that the source device transmits a power corresponding to the determined amount of the wireless power.

The controller **530** controls the operation of the channel search unit **510**, regardless of whether the target device is waked up. For example, before the target device is detected, the controller **530** controls the channel search unit **510** to search for communication channels available for communication in the source device.

In an example in which the source device is not accessed by a target device, the controller **530** controls the operation of the channel search unit **510** based on a channel search start command. For example, if a user pushes a start button attached to the source device, the channel search start command is input.

In another example in which the source device is accessed by a target device, the controller **530** controls the operation of the channel search unit **510** based on an amount of a change in a current output from the source device. This is because the current output from the source device may be changed if another target device is added, or if the target device disappears.

If the source device is operated in the power access mode, the controller **530** determines whether the source device is accessed by the target device based on information on a power of a communication output of the source device, and information on a power of the communication output received by the target device. The power of the communication output of the source device refers to a power used to transmit data via a communication channel. If a difference between the power of the communication output of the source device and the power of the communication output received by the target, is less than a predetermined reference, the controller **530** permits the target device to access the source device. As a distance between the source device and the target device is reduced, a low amount of the power of the communication output transmitted from the source device to the target device may be lost. The source device may permit an access by a target device located near the source device first.

The controller **530** may determine a difference between a wireless power transmitted by the source device and a power transferred to a load of the target device, and may determine whether the target device incorrectly accesses the source device based on the calculated difference. If the calculated difference is greater than a predetermined reference, the controller **530** determines that the target device incorrectly accesses the source device. In other words, whether the target device incorrectly accesses the source device may be determined based on a wireless power transmission efficiency.

Additionally, the controller **530** may determine a difference between a time in which an amount of the wireless power transmitted by the source device is changed to a predetermined value, and a time in which an amount of the power transferred to the load of the target device is changed, and may determine whether the target device incorrectly accesses the source based on the calculated difference. If the calculated difference is greater than a predetermined reference, the controller **530** determines that the target device incorrectly accesses the source device.

If an interference signal including an intensity level greater than or equal to a channel selection reference level (i.e., of intensity), is measured in each of the communication channels as a result of measuring the state information of the communication channels, the channel determining unit **520** determines a communication channel with an interference signal including a lowest intensity level, among the measured intensities, to be the communication channel available for communication with the target device. Otherwise, the chan-

nel determining unit **520** determines a communication channel with an interference signal of a level less than or equal to the channel selection reference level, among the measured intensities to be the communication channel available for communication with the target device.

The controller **530** determines a power level of the communication output of the source device based on a table to which an intensity level of an interference signal in the determined communication channel, and a power level of an output signal required to transmit data within a predetermined error range, are mapped. As the intensity level of the interference signal increases, the power level of the communication output of the source device may need to increase, to transmit data within the predetermined error range.

If a value of an error in a communication channel between the source device and the target device becomes greater than a predetermined reference value, or if an intensity of an interference signal detected from the determined communication channel is greater than a predetermined value, the controller **530** determines to change the determined communication channel to another communication channel. The controller **530** determines a new communication channel using the channel determining unit **520**. The controller **530** transmits, to the target device, a channel change request instruction including information on the new communication channel.

The controller **530** controls an overall operation of the communication apparatus **500**, and performs functions of the channel search unit **510**, the channel determining unit **520**, and the communication unit **540**. To individually describe functions of the channel search unit **510**, the channel determining unit **520**, the controller **530**, and the communication unit **540**, the channel search unit **510**, the channel determining unit **520**, the controller **530**, and the communication unit **540** are separately illustrated in FIG. **5**. However, if the communication apparatus **500** of FIG. **5** is implemented, the controller **530** may be configured to perform all of the functions, or only a portion of the functions.

FIG. **6** illustrates another example of a communication apparatus **600** in a wireless power transmission system. The communication apparatus **600** includes a communication unit **610**, a controller **620**, a channel search unit **630**, and a channel determining unit **640**. The communication apparatus **600** of FIG. **6** may correspond to a target device in the wireless power transmission system.

The channel search unit **630** searches for communication channels. The communication channels may be different from a channel used in wireless power transmission. The target device may receive a power using a wireless power transmission channel, and may transmit and receive data using a communication channel. The communication channels may be channels in an ISM band.

The channel search unit **630** selects an n-th channel, as a first target to be searched for, from among searchable channels. For example, channels may be searched for in a descending order, in an ascending order, or in a random order.

The channel search unit **630** may search for communication channels based on a search table. The search table may be set differently based on a type of a target device or a unique ID assigned to the target device. The channel search unit **630** may search for communication channels in different orders for each type of the target device, as illustrated in the example of Table 2. In an example in which the target device corresponds to a type 1, the channel search unit **630** may sequentially search for 16 channels from a channel 7. In another example in which the target device corresponds to a type 5, the channel search unit **630** may sequentially search for the 16 channels from a channel 9.

TABLE 2

| | Search table (16 channels, 1~16) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of target, or unique ID assigned to target | Type1 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 |
| | Type2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 |
| | Type3 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | Type4 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 |
| | Type5 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | Type6 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | Type7 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | Type8 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | Type9 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 |
| | Type10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Type11 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 |
| | Type12 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | Type13 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 |
| | Type14 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Type15 | 13 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | Type16 | 14 | 15 | 16 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |

The channel search unit **630** measures state information of one or more communication channels. The state information may include information on a channel seizure signal transmitted by the source device. The channel seizure signal may include a predetermined intensity. For example, the channel seizure signal may be a CW signal including a predetermined intensity and a power greater than a communication signal of a DSSS. The channel seizure signal may be modulated using a predetermined modulation scheme. The channel search unit **630** may search for a channel that enables receiving of a CW signal. The channel search unit **630** may measure an RSSI of a communication channel, and may determine whether the channel seizure signal is received based on the RSSI.

The channel determining unit **640** determines a communication channel available for communication with the source device based on the state information of the communication channels. The channel determining unit **640** may determine a channel in which a channel seizure signal including an intensity exceeding a predetermined reference value is measured, to be the communication channel available for communication with the source device. The channel seizure signal may be received from the source device, and may include a predetermined intensity. An intensity of the channel seizure signal received by the target device may be determined based on a distance between the source device and the target device. The source device and the target device may agree to communicate with each other within a predetermined distance only.

The controller **620** determines whether to communicate with the source device based on whether an access standard instruction is received from the source device within a reference time using a communication frequency of the determined communication channel. The reference time may be set in advance based on a state of a battery of the target device, and/or other factors known to one of ordinary skill in the art.

For example, if data of communication networks other than the access standard instruction is received, the controller **620** determines that the received data is different from the access standard instruction, due to different packet structures. If the access standard instruction is not received within the reference time, the controller **620** controls the channel search unit **630** to search for another communication channel.

The access standard instruction may include information used for compatibility between a source device and a target device. The access standard instruction may include a call argument and a call parameter used to identify target devices. For example, if the same identifying parameter as a call parameter is included in the target device, the target device transmits a response signal.

The communication unit **610** receives an access standard instruction from a source device. For example, if the access standard instruction is received within a reference time, the communication unit **610** transmits a response signal corresponding to the access standard instruction.

The communication unit **610** receives a control ID assigned to the target device from the source device. If the response signal corresponding to the access standard instruction is received, the source device assigns the control ID to the target device.

For example, if channel seizure signals are received from source devices, the controller **620** determines a source device that uses a communication channel with a channel seizure signal including a largest intensity, from among the source devices, to be a source device that the target device desires to access. In this example, the channel determining unit **640** determines the communication channel with the channel seizure signal including the largest intensity to be the communication channel available for communication with the source device.

The controller **620** determines a power required by the target based on a power measured at an input end of a DC/DC converter included in the target device, a power measured at an output end of the DC/DC converter, and a power transferred to a load of the target device. The communication unit **610** transmits, to the source device, information on the power measured at the input end of the DC/DC converter, and information on the power measured at the output end of the DC/DC converter. The source device may adjust a power to be transmitted to the target device so that the power measured at the input end of the DC/DC converter may include a similar value to the power measured at the output end of the DC/DC converter. The source device receives information on the power required by the target device, in real time or periodically, and accordingly, may efficiently transmit the power required by the target device to the target device.

The communication unit **610** receives a channel change request instruction from the source device. The controller **620** changes a channel used to access the source device based on communication channel information included in the channel change request instruction. The communication unit **610** may not transmit an acknowledgement (ACK) signal.

The controller **620** controls an overall operation of the communication apparatus **600**, and performs functions of the communication unit **610**, the channel search unit **630**, and the channel determining unit **640**. To individually describe functions of the communication unit **610**, the controller **620**, the channel search unit **630**, and the channel determining unit **640**, the communication unit **610**, the controller **620**, the channel search unit **630**, and the channel determining unit **640** are separately illustrated in FIG. **6**. However, if the communication apparatus **600** of FIG. **6** is implemented, the controller **620** may be configured to perform all of the functions, or only a portion of the functions.

FIG. **7** illustrates an example of communication channels that may be used in a wireless power transmission system. In the wireless power transmission system, a communication apparatus may use channels in an ISM band. In more detail, the communication apparatus may use, as a communication channel, a single channel among 16 channels CH1 through CH16 with a channel spacing of 5 megahertz (MHz) in a range of 2405 MHz to 2480 MHz.

FIG. **8** illustrates an example of a method a target device determining a communication channel based on a CW signal in a wireless power transmission system. The wireless power transmission system includes a power source device and a mobile device. The mobile device corresponds to a target device. The power source device transmits a power, and the mobile device receives the power. To efficiently transmit the power to the mobile device, the power source device may need to be aware of information on a state of the mobile device. In other words, the power source device and the mobile device may need to communicate with each other, to exchange information on a state of the power source device and the information on the state of the mobile device with each other.

The power source device may search for communication channels in an ISM band. Additionally, the power source device may measure an RSSI for each of the communication channels, and may determine a communication channel in which an RSSI is less than a reference value, to be a communication channel available for communication with the mobile device.

To communicate with the mobile device using the determined communication channel, the power source device raises a power in the determined communication channel, and transmits a channel seizure signal in the determined communication channel. While searching for communication channels in the ISM band, the mobile device may determine the communication channel receiving the channel seizure signal, to be a communication channel available for communication with the power source device. The channel seizure signal may be, for example, a CW signal, a modulated signal, or a predetermined signal. Such a method of determining a communication channel by detecting a channel seizure signal between the power source device and the mobile device may be referred to the term "multi-channel carrier sense-seizure of channel (MCCS-CS)".

For example, if channel seizure signals are received, the mobile device may determine a communication channel with a channel seizure signal including a largest intensity among the received channel seizure signals, to be a communication channel available for communication with the power source device. The mobile device may access the power source device using the determined communication channel.

Referring to FIG. **8**, a first mobile device (i.e., a mobile device **1**) receives CW signals CW**1** and CW**2** from a first power source device (i.e., a power source device **1**) and a second power source device (i.e., a power source device **2**), respectively. CW signals transmitted by the same type of power source devices may include the same intensity. Accordingly, an intensity of a CW signal received by a mobile device may be determined based on a distance between the

mobile device and a power source device. Since a distance between the first mobile device and the first power source device is shorter than a distance between the first mobile device and the second power source device, an intensity of the CW signal CW**1** is greater than an intensity of the CW signal CW**2**. The first mobile device communicates with the first power source device using a communication channel receiving the CW signal CW**1**, and accesses the first power source device. Subsequently, the first mobile device receives a power from the first power source device.

A CW signal may be used to identify the same type of power source devices, and to identify different types of communication devices. Additionally, the CW signal may be used by a target device to identify communication channels. The CW signal may be a carrier frequency signal that is not modulated using an offset-quadrature phase-shift keying (O-QPSK), and an occurrence of the CW signal may be controlled by a frequency synthesizer.

To communicate with a target device based on a channel assignment policy, a source device may select a channel. The target device may be, for example, a charging terminal. In wireless power transmission, 16 channels may be physically supported. Each of the 16 channels may be generated with different energy intensities. When wireless power transmission is started, the source device may perform energy detection of interference signals caused by different types of devices, and on CW signals occurring from source devices of the same type as the source device. The source device may perform energy detection if all channels based on a frequency channel policy. The energy detection may be used by the source device to search for a channel to communicate with multiple target devices, in a charging environment of the multiple target devices.

The CW signal may be used to detect a channel. In addition, to detect a channel, a modulated signal or a predetermined signal may be used. To transfer information on the detected channel, the source device may increase an intensity of the CW signal in the detected channel, and may enable the target device to easily detect the channel. Accordingly, the target device may easily identify a channel available for communication based on a CW signal including a large intensity.

For example, if an unused channel is found as a result of searching, a source device may set transmission of a CW signal for stable communication between the source device and a target device. In this example, if the transmission of the CW signal is set by the source device, the target device may stably detect an RSSI or LQI, which may facilitate detection of a channel.

In a multi-charging environment, if a source device detects a channel, a value of an RSSI based on an intensity of a CW signal may be used to determine which type of device interferes with the source device. In other words, the CW signal may be used to determine whether a device that is of the same type as the source device and that transmits a wireless power, or a device that is of a different type than the source device and that does not transmit wireless power, interferes with the source device. In an example in which a device of the same type as the source device interferes with the source device, a difference in RSSI level of a CW signal may occur. In another example in which a device of a different type than the source device interferes with the source device, a difference between a DSSS and a level of the CW signal may occur.

If the same channel is shared with a device of the same type as the source device, the source device may use a CW signal to determine whether the channel is available. If a charging source device is added by using the CW signal as a channel seizure signal, a distance between the source device and the charging source device may be determined.

The target device may use a CW signal to identify an interference with a communication channel. The target device may distinguish a typical interference signal from a CW signal, and may quickly detect a communication channel. To determine a communication channel, the target device may determine whether a CW signal is received, and verify state information of a source device. The target device may attempt to access the source device, only if an access standard instruction is received.

FIG. **9** illustrates examples of powers of CW signals received by a target device in a wireless power transmission system. In a channel with a central frequency of 2405 MHz, a communication power of an interference signal received from neighboring electronic devices corresponds to a signal of a DSSS. The signal of the DSSS includes a bandwidth of 5 MHz. The signal of the DSSS is lesser in intensity than, and is wider in bandwidth than, CW signals received from the same type of source devices.

The target device determines a channel, and a source device to communicate with the target device, based on an intensity of a channel seizure signal received via the channel. Referring to FIG. **9**, the target device receives CW signals CW**1** and CW**2** (i.e., channel seizure signals) using the same channel. Since a power of the CW signal CW**1** is greater than a power of the CW signal CW**2**, the target device determines to access a source device transmitting the CW signal CW**1**, and determines the channel with the central frequency of 2405 MHz to be a communication channel.

FIG. **10** illustrates examples of powers of communication channel signals received by a target device in a wireless power transmission system. Source devices transmit channel seizure signals using the same communication scheme as neighboring electronic devices (i.e., the same out-band channel and same bandwidth), unlike in FIG. **9**. However, the source devices increases a power of the channel seizure signals, compared to a communication power of an interference signal received from the neighboring electronic devices, and transmits the channel seizure signals with the increased power.

For example, the target device receives a first channel seizure signal and a second channel seizure signal of a channel detection power 1 and a channel detection power 2, respectively. The target device compares the channel detection power 1 with the channel detection power 2. Since the channel detection power 1 is greater than the channel detection power 2, the target device accesses a source device transmitting the first channel seizure signal. Additionally, to communicate with the source device transmitting the first channel seizure signal, the target device determines the out-band channel to be a communication channel.

FIG. **11** illustrates an example of an interference signal influencing a source device in a wireless power transmission system. In more detail, a source device S**1** **1110** searches for a communication channel. If the communication channel is found, the source device S**1** **1110** receives an interference signal from a WLAN **1130**. The WLAN **1130** may be of a different type from the source device S**1** **1110**, and may not transmit wireless power. Additionally, the source device S**1** **1110** receives a CW signal from a source device S**2** **1120**. The source device S**2** **1120** is of the same type as the source device S**1** **1110**, and transmits a wireless power. The source device S**1** **1110** measures an intensity (e.g., an RSSI) of the interference signal and an intensity (e.g., an RSSI) of the CW signal, for each communication channel. If one of the intensities is

less than or equal to a predetermined value, the source device S1 **1110** determines a corresponding channel to be a communication channel.

FIG. **12** illustrates an example of a timing in which a source device determines a communication channel in a wireless power transmission system. The source device searches for communication channels, and detects an RSSI for each of the communication channels.

In a time $T_{S_PLL}$ **1201**, the source device adjusts a channel frequency to be a frequency of a channel to be searched for. In a time $T_{DLY}$ **1203**, the source device stabilizes the adjusted channel frequency. In a time $T_{CHK}$ **1205**, the source device detects an RSSI of the channel. If a level of the RSSI of the channel is greater than a reference value, the source device determines that the channel is being used, and searches for a next channel, as shown herein.

In a time $T_{S_PLL}$ **1211**, the source device adjusts a channel frequency to be a frequency of the next channel. In a time $T_{DLY}$ **1213**, the source device stabilizes the adjusted channel frequency. In a time $T_{CHK}$ **1215**, the source device detects an RSSI of the next channel. If a level of the RSSI of the next channel is less than or equal to the reference value, the source device determines the next channel to be a communication channel for communication with a corresponding target device, as shown herein. The time $T_{CHK}$ **1215** may be set differently based on a type of the source device, or a type of a target device accessing the source device.

In a time $T_{CON}$ **1221**, the source device transmits an access standard instruction. In a time $T_D$ **1223**, the source device waits for reception of a response signal corresponding to the access standard instruction. The access standard instruction may include information used to connect the source device and the target device. Additionally, the access standard instruction may include an instruction to request state information of the target device. In a time $T_{CON}$ **1231**, the source device transmits a new access standard instruction. In a time $T_D$ **1233**, the source device waits for reception of a response signal corresponding to the new access standard instruction.

FIG. **13** illustrates an example of a timing in which a target device determines a communication channel in a wireless power transmission system. The target device searches for communication channels, and detects an RSSI for each of the communication channels.

In a time $T_{S_PLL'}$ **1301**, the target device adjusts a channel frequency to be a frequency of a channel to be searched for. In a time $T_{DLY'}$ **1303**, the target device stabilizes the adjusted channel frequency. In a time $T_{CHK'}$ **1305**, the target device detects an RSSI of the channel to determine whether a channel seizure signal is received via the channel. If the level of the RSSI is less than a reference value, the target device determines that the source device does not transmit a channel seizure signal, and searches for a next channel, as shown herein.

In a time $T_{S_PLL'}$ **1311**, the target device adjusts a channel frequency to be a frequency of the next channel. In a time $T_{DLY'}$ **1313**, the target device stabilizes the adjusted channel frequency. In a time $T_{CHK'}$ **1315**, the target device detects an RSSI of the next channel. If a level of the RSSI of the next channel is greater than or equal to the reference value, the target device determines the next channel to be a communication channel for communication with a corresponding source device, as shown herein. The time $T_{CHK'}$ **1315** may be set differently based on a type of the target device, or a type of the source device accessed by the target device.

In a time $T_{CHK_C}$ **1321**, the target device waits for reception of an access standard instruction from the source device. If the access standard instruction is not received in the time $T_{CHK_C}$ **1321**, as shown herein, in a time $T_{S_PLL'}$ **1331**, the target device again adjusts a channel frequency to be a frequency of a next channel. In a time $T_{DLY'}$ **1333**, the target device stabilizes the adjusted channel frequency. In a time $T_{CHK'}$ **1335**, the target device detects an RSSI of the next channel. If a level of the RSSI of the next channel is greater than or equal to the reference value, the target device determines the next channel to be a communication channel for communication with a corresponding new source device, as shown herein.

In a time $T_{CHK_C}$ **1341**, the target device waits for reception of a new access standard instruction from the new source device. If the new access standard instruction is received in the time $T_{CHK_C}$ **1341**, as shown herein, in a time **1343**, the target device transmits an ACK signal to the new source device.

FIG. **14** illustrates an example of wireless power transmission systems placed in a cell unit. Each of the wireless power transmission systems includes a power source device and at least one mobile device. The mobile device corresponds to a target device.

The wireless power transmission systems are managed in the cell unit. A cell includes regions in which channels may be used. A relationship between cells of FIG. **14** and channels may be defined, as illustrated in the example of Table 3.

TABLE 3

| | Available channel | Interference channel | Shared channel |
|---|---|---|---|
| Cell 1 | Ch1, Ch2, Ch3, Ch4, Ch5, Ch6, Ch7 | Ch8, Ch9, Ch10, Ch11, Ch12, Ch13, Ch14, Ch15, Ch16 | Cell 2 - Ch1, Ch4<br>Cell 3 - Ch4, Ch7 |
| Cell 2 | Ch1, Ch4, Ch8, Ch9, Ch10, Ch11, Ch12 | Ch2, Ch3, Ch5, Ch6, Ch7, Ch13, Ch14, Ch15, Ch16 | Cell 1 - Ch1, Ch4<br>Cell 3 - Ch4, Ch8 |
| Cell 3 | Ch4, Ch7, Ch8, Ch13, Ch14, Ch15, Ch16 | Ch1, Ch2, Ch3, Ch5, Ch6, Ch9, Ch10, Ch11, Ch12 | Cell 1 - Ch4, Ch7<br>Cell 2 - Ch4, Ch8 |

In Table 3, an available channel refers to a channel that may be used to perform communication in a wireless power transmission system. Additionally, an interference channel refers to a channel that may not be used due to interference of signals generated from networks, such as, for example a WLAN 802.11, a WPAN 802.15, and a WMAN 802.16. A shared channel refers to a channel that may be shared since a distance between regions in different cells is greater than a predetermined reference. In the shared channel, an interference signal may include a low level, and interference may be less likely to occur between different cells. Whether a channel in a cell is available in another cell may be determined based on whether a value of an LQI or a value of an RSSI is less than or equal to a reference value. For example, referring to FIG. **14**, wireless power transmission systems in the region **1410** and region **1420**, respectively, share a channel CH1, wireless power transmission systems in the region **1430** and region **1440**, respectively, share a channel CH4, and wireless power transmission systems in the region **1450** and region **1460**, respectively, share a channel CH7.

Referring to Table 3 and FIG. **14**, a cell 1 and a cell 2 share channels CH1 and CH4, and the cell 1 and a cell 3 share channels CH4 and CH7. Additionally, the cell 2 and the cell 3 share channels CH4 and CH8.

For example, when source devices of the same type are used in a short distance, a target device required to be charged may access a source device other than a desired source device that the target device needs to access. To prevent the target device from accessing a source device other than the desired

source device, a basic processing scheme, a processing scheme in an access mode, a processing scheme in a charging mode, and a processing scheme of preventing an error in access, may be provided.

In a basic processing scheme, to prevent the target device from incorrectly accessing a source device other than the desired source device, among the source devices of the same type, the desired source device may be operated in a master mode. The desired source device in the master mode may process an access by the target device, regardless of whether the target device is waked up.

In an example in which no target device accesses a source device, the source device may start processing an access of a target device using only a start button. Only the source device, of which the start button is pushed, among the source devices, may process the access, and accordingly, a possibility for the target device to incorrectly access another source device may be reduced. Additionally, it is possible to reduce waste of unnecessary power in a standby mode. In another example in which a target device accesses a source device, if a supplied current is changed in the source device, the source device may process the access by the target device.

In a processing scheme in an access mode, if an access standard instruction is transmitted from a source device to a target device, or if a source device transmits an access standard instruction using a communication channel, information on used power may be included in the access standard instruction, and may be transferred to the target device. The target device may transfer the received information, and information on a power to be transmitted, to the source device, and accordingly, it is possible to prevent the target device from incorrectly accessing the source device.

In more detail, the source device may transmit, to the target device, an access standard instruction including a communication output of a control channel, namely, a communication channel. The target device may transmit, to the source device, a response signal including a value of an LQI or a value of an RSSI of a packet received from the source device, and including a communication output of a current control channel.

Based on the information acquired by the above methods, the source device may verify the LQI or RSSI of the packet received by the target device, the communication output transmitted by the target device, and an LQI or RSSI of a packet transmitted by the target device, compared to the communication output of the source device. The source device may calculate a distance between the source device and the target device based on the verified information. Exchanging of the information on the communication output of the source device and information on the communication output of the target device with each other, may be required to prepare for adjustment of an output of a control channel based on a usage environment, and of an applied product, and may be required to prepare for a case in which the source device and the target device independently determine an incorrect access.

In a processing scheme in a charging mode, if target devices are being charged by source devices A and B in a short distance, and if a new target device approaches the source devices A and B, which one of the source devices A and B to be accessed by the new target device, may need to be determined. In this example, a target device may incorrectly access a source device since at least two source devices of the same type are located close enough to the target device. The source device A may be incorrectly accessed by the target device, and the source device B may need to be accessed by the target device. Additionally, a target device C may be required to be charged.

The source device A may raise a power, and transmit a higher power to the target device C; however, a relatively low power may be transferred to the target device C, compared to a normal access. The source device A may regularly receive, from the target device C, a power of an input end of the target device C, a power of an output end of the target device C, and state information of the target device C. The source device A may determine that the target device C incorrectly accesses the source device A based on the received power of the input end of the target device C, the received power of the output end of the target device C, and the received state information of the target device C.

The source device A may transmit a target reset instruction to the target device C, and may cancel registration of a control ID assigned to the target device C. Additionally, the source device A may enable a light-emitting diode (LED) indicator indicating a charging mode to flicker for five seconds.

In response to the target reset instruction, the target device C may be initialized, and may be automatically disconnected from the source device A. Subsequently, the target device C may determine whether to access the source device B based on a state of the source device B.

If no target device accesses the source device B, and if the target device C is initialized before a maximum access time elapses, the target device C may directly access the source device B. For example, the maximum access time may be from about 5 seconds to 10 seconds. The maximum access time may be adjusted based on user conveniences. If the target device C is initialized after the maximum access time elapses, a user may re-push a charging start button of a source device.

If a target device accesses the source device B, a current supplied in the source device B may be changed due to an access by the target device C. Accordingly, the source device B may detect a change in the supplied current, and may process the access.

In a processing scheme of preventing error in access, a source device may adjust an output level of a CW signal to a target device, and may reduce a communication distance. The source device may detect the output level of the CW signal, and may verify the communication distance, based on an RSSI table written for each distance from the source device.

A target device may re-adjust a transmission mode, namely, a time in which a response signal or other signals are transmitted. The target device may further reduce a time required to connect a channel and to perform communication between a source device and the target device.

A source device may display an access attempt event (i.e., a flag), and may use the access attempt event to indicate a source device that is attempting to access. The source device may insert, in a transmitted packet, state indication information indicating that an attempt to access is being performed.

If it is difficult to perform communication due to an interference occurring in a communication channel between a source device and a target device, the source device may transmit a channel change request instruction, and may change the communication channel. Whether an interference of a channel occurs, and a level of an interference, may be determined based on a packet error and a communication error packet counter.

If a source device performs communication in a dense space, a communication reception sensitivity may be reduced. The source device may increase a communication output level in only a communication interval.

A source device may cancel a general instruction if an access standard instruction is transmitted to a target device. A source device may prevent a target device from being operated in an access mode, in a maximum access state.

FIG. **15** illustrates an example of communication networks influencing communication channels of source devices in a wireless power transmission system. When source devices **S1** and **S2** search for communication channels, a WPAN 802.15 may interfere with the source devices **S1** and **S2** in a channel CH1, a WMAN 802.16 may interfere with the source devices **S1** and **S2** in a channel CH2, and a WLAN 802.11 may interfere with the source devices **S1** and **S2** in a channel CH3. In an example in which three communication channels, namely, the channels CH1 to CH3, are available to the source devices **S1** and **S2**, a reference to determine a communication channel may be required. The source devices **S1** and **S2** may wait until the interference is reduced, and may then determine a communication channel. Other channel determination references will be described with reference to FIG. **16**.

FIG. **16** illustrates an example of intensities of signals detected from communication channels in a wireless power transmission system. Interference signals include intensity levels **1620**, **1630**, and **1640**, respectively, which are higher than a channel selection reference level **1610**. The levels **1620**, **1630**, and **1640** are detected from channels CH1, CH2, and CH3, respectively. A WPAN 802.15, a WMAN 802.16, and a WLAN 802.11 may interfere with the channels CH1, CH2, and CH3. A first source device may select, as a communication channel, the channel CH1 with the interference signal including a lowest intensity level among the channels CH1, CH2, and CH3, and may transmit a CW signal CW**1** **1650** to a target device. Subsequently, a second source device may select, as a communication channel, the channel CH2 with the interference signal including a lower intensity level among the channels CH2 and CH3, and may transmit a CW signal CW**2** **1660** to the target device.

FIG. **17** illustrates an example of a relationship between a power of a signal interfering with a communication channel of a source device, and an input power in the communication channel, in a wireless power transmission system. For example, if the source device selects a communication channel from among communication channels in which levels of interference signals are higher than a channel selection reference level, an input power of the selected communication channel may need to be increased based on a power level of an interference signal of the selected communication channel, to reduce a data transmission error rate. Referring to FIG. **17**, when an output of an interference signal (namely, an interferer power) is increased, a power input into a communication channel may also need to be increased, to reduce a data transmission error rate to less than 1%.

FIG. **18** illustrates an example of a communication distance based on an adjustment of a power output from a power source device in a wireless power transmission system. That is, the power source device adjusts a distance enabling communication, by adjusting an output power level of a communication channel. The power source device adjusts the distance to be suitable for a charging pad. For example, if the output power level of the power source device corresponds to a power 1, communication may be performed in a region with a radius R**1**. In this example, the power source device may adjust the output power level from the power 1 to a power 3, which changes the region with the radius R**1** to a region with a radius R**3**, so that the communication may be performed in the region with the radius R**3**.

For example, the power source device may be implemented in the form of a pad. In this example, an antenna with a radiation pattern, and/or a chip antenna, may be used. A target device may use, for example, a flexible printed circuit board (FPCB) type antenna, for directivity and near field communication.

FIG. **19** illustrates an example of a position of a target device in a wireless power transmission system. In the wireless power transmission system, a source device may include a source resonator, and a target device may include a target resonator. A power transferred to the target resonator among a power transmitted via the source resonator, namely, a wireless power transmission efficiency, may be measured based on a position of the target resonator located above the source resonator, as illustrated in the example of FIG. **19** and Table 4. FIG. **19** and Table 4 shows that the wireless power transmission efficiency varies based on the position of the target resonator. For example, in positions (3) and (4), a relatively low wireless power transmission efficiency is measured.

TABLE 4

| Position | Efficiency (%) | Position | Efficiency (%) |
|---|---|---|---|
| (1) | 88.33 | (8) | 87.02 |
| (2) | 88.84 | (9) | 91.07 |
| (3) | 78.25 | (10) | 84.65 |
| (4) | 79.79 | (11) | 83.68 |
| (5) | 90.47 | (12) | 91.22 |
| (6) | 85.99 | (13) | 86.83 |
| (7) | 88.47 | (14) | 91.23 |
| (R1) | 88.17 | (R2) | 88.73 |

FIG. **20** illustrates an example of a power transmission efficiency based on a position of a target device in a wireless power transmission system. In the wireless power transmission system, a source device may include a source resonator, and the target device may include a target resonator.

Referring to FIG. **20**, the source device may adjust an amount of a power transmitted via the source resonator, so that a power transferred to the target resonator among the power transmitted via the source resonator may be maintained, regardless of a position of the target resonator located above the source resonator. In an example in which a power value detected in the source device is greater than or equal to a power value of an over protection current, the wireless power transmission system is turned off. In another example in which a reference efficiency of a wireless power transmission efficiency is 50%, the source device controls the transmitted power to be within a range of ±5% compared to the reference efficiency (i.e., a power control sector), regardless of the position of the target resonator.

To control the power, a power tracking scheme may be used. The power tracking scheme may be used to control a supplied voltage based on an output power level so that an E-class power amplifier may be operated in a saturation region. A scheme of controlling the supplied voltage may include a scheme of using an external SMPS, and/or a scheme of using a commercialized SMPS, and may be applied based on a used application.

FIG. **21** illustrates an example of a communication method in a wireless power transmission system. In operation **2101**, a source device initializes an SCB. The source may initialize updated system information in the SCB to system information set at a time of manufacturing the source device. The system information may include, for example, a serial number of the source device, a maximum number of target devices accessible to the source device, a power transmission parameter, a communication channel parameter, and/or other information known to one of ordinary skill in the art.

In operation **2103**, the source device determines whether a start button is input in the source device. The source device prepares for transmission of wireless power based on the input of the start button. The input of the start button may

indicate that a target device is located in a wireless power transmission region of the source device.

If the start button is input, in operation **2105**, the source device transmits a wake-up power required to operate a controller of the target device. Otherwise, the source device returns to operation **2103**.

In operation **2107**, the source device searches for communication channels in a search order. The source device sets one of the communication channels to potentially be a communication channel available for communication with the target device.

In operation **2109**, the source device detects an RSSI of the set communication channel, and determines whether the detected RSSI is less than a reference value. The RSSI indicates an intensity of an interference signal in the communication channel affected by neighboring communication devices.

If the detected RSSI is greater than or equal to the reference value, in operation **2111**, the source device searches for a new channel and returns to the operation **2107**. Otherwise, in operation **2113**, the source device determines the set communication channel to be the communication channel available for communication with the target device, transmits a channel seizure signal based on a communication frequency of the set communication channel. The channel seizure signal may be a CW signal. The source device may continue to transmit the channel seizure signal while the set communication channel is used.

In operation **2115**, the source device transmits an access standard instruction. The access standard instruction may include information used for compatibility between the source device and the target device. The access standard instruction may further include a call argument and a call parameter used to identify target devices. For example, if the same identifying parameter as the call parameter is included in the target device, the target device transmits a response signal to the source device.

In operation **2117**, the source device determines whether the response signal (e.g., an ACK signal) is received from the target. If the ACK is not received, in operation **2119**, the source device determines whether the access standard instruction is transmitted a maximum number of times. For example, if the call argument in the access standard instruction is set to "3", the call parameter may include a value from "000" to "111". In this example, the source device may transmit the access standard instruction eight times.

If the access standard instruction is not transmitted the maximum number of times, in operation **2121**, the source device changes the call parameter, e.g., increments the value of the call parameter. Otherwise, the source device returns to operation **2103**.

If the ACK is received, in operation **2123**, the source device assigns a control ID to the target device. The source device transmits the control ID to the target device.

FIG. **22** illustrates another example of a communication method in a wireless power transmission system. In operation **2201**, a target device initializes an SCB. The target may initialize updated system information in the SCB to system information used at a time of manufacturing the target device. The system information may include, for example, a serial number of the target device, a battery type, a power transmission parameter, a communication channel parameter, and/or other information known to one of ordinary skill in the art.

In operation **2203**, the target device searches for communication channels in a search order. The target device sets one of communication channels to potentially be a communication channel available for communication with a source device.

In operation **2205**, the target device detects an RSSI of the set communication channel, and determines whether the detected RSSI is greater than or equal to a reference value. The RSSI indicates an intensity of a channel seizure signal received from the source device. For example, the RSSI may indicate an intensity of a CW signal.

If the detected RSSI is less than the reference value, in operation **2207**, the target device searches for a new channel and returns to operation **2203**. Otherwise, in operation **2209**, the target device determines the set communication channel to be the communication channel available for communication with the source device. The target device determines whether an access standard instruction is received from the source device. The access standard instruction may include information used for compatibility between the source device and the target device. The access standard instruction may further include a call argument and a call parameter used to identify target devices. For example, if the same identifying parameter as a call parameter is included in the target device, the target device transmits a response signal to the source device.

If the access standard instruction is not received, in operation **2211**, the target device determines whether a reference time elapses. If the reference time does not elapse, the target device returns to operation **2209** to wait for reception of the access standard instruction until the reference time elapses. If the reference time elapses, the target device returns to operation **2203** to set another one of the communication channels in the search order.

If the access standard instruction is received, in operation **2213**, the target device transmits the response signal (e.g., an ACK signal) to the source device. In operation **2215**, the target device determines whether a control ID is received from the source device.

If the control ID is received, in operation **2217**, the target device transmits an ACK signal to the source device. Otherwise, the target device returns to operation **2215** to wait for reception of the control ID When the source device assigns the control ID to the target device, the source device may call the control ID, and may request state information of the target device.

FIG. **23** illustrates still another example of a communication apparatus in a wireless power transmission system. Referring to FIG. **23**, the communication apparatus transmits a signal modulated in a source via a communication transceiver **2310** and a medium access control (MAC) **2320**, and receives a signal modulated in a target via the communication transceiver **2310** and the medium access control (MAC) **2320**. Thus, the communication apparatus in FIG. **23** performs out-of-band communication between the source and the target via the communication transceiver **2310**, rather than performing in-band communication through the source resonator **2340**. A PHY controller **2330** controls an overall operation associated with modulation of data and generation of wireless power in the communication apparatus. A source resonator **2340**, for example a wireless power transmitter, transmits wireless power using mutual resonance with a target resonator (not shown).

A first demodulator **2351**, for example an offset-quadrature phase-shift keying (O-QPSK) demodulator, performs O-QPSK demodulation. A second demodulator **2353**, for example a chip demodulator, performs demodulation using a pseudo-random noise (PN) sequence. A symbol demapper **2355** generates a data symbol corresponding to a quadrature-

phase (Q) value and an in-phase (I) value. A decoder **2357**, for example a Viterbi decoder, decodes the data symbol using a Viterbi scheme. The decoder **2357** uses a Viterbi algorithm to decode an encoded bit stream received from the symbol demapper **2355** using forward error correction (FEC) based on a convolution code. Although FIG. **23** shows the decoder **2357** as being part of the communication apparatus in FIG. **23**, the decoder **2357** may be provided as a separate element outside the communication apparatus of FIG. **23**.

A channel detector **2361** detects an RSSI. The RSSI is a value obtained by measuring a strength of an electric wave of data transferred by neighboring devices. A frame detector **2363** detects an LQI of a communication link. The LQI is a strength between communication links, and may be calculated from the RSSI.

An encoder **2377**, for example a convolution encoder, encodes an input signal, and outputs the encoded signal. The encoder **2377** may successfully perform bit error checking using an additional bit. Although FIG. **23** shows the encoder **2377** as being part of the communication apparatus in FIG. **23**, the encoder **2377** may be provided as a separate element outside the communication apparatus of FIG. **23**. A symbol mapper **2375** performs mapping to appropriately arrange symbols based on a designated modulation scheme. A second modulator **2373**, for example, a direct sequence spread spectrum (DSSS) chip modulator, spreads data to a large-scale code flow occupying a full bandwidth of a corresponding channel by multiplying a data bit by a random bit pattern, namely a pseudo-random noise (PN) sequence. Such a scheme has a good noise prevention performance, and provides excellent security because the spread data is very difficult to recover without knowing the pseudo-random noise (PN) sequence. A first modulator **2371**, for example an O-QPSK modulator, performs O-QPSK modulation.

A protection unit **2387** prevents an overcurrent from being supplied to a power amplifier **2385**. The power amplifier **2385** generates power required by the target. A detector **2383** detects a change in impedance of the target. Additionally, the detector **2383** may detect power input to the power amplifier **2385**. A tracking unit **2381** tracks matching impedance between the source and the target. Additionally, the tracking unit **2381** may track a resonant frequency between the source and the target.

In the following description, the term "resonator" used in the discussion of FIGS. **24**A through **26**B refers to both a source resonator and a target resonator.

FIGS. **24**A and **24**B illustrate examples of a distribution of a magnetic field in a feeder and a resonator of a wireless power transmitter. When a resonator receives power supplied through a separate feeder, magnetic fields are formed in both the feeder and the resonator.

FIG. **24**A illustrates an example of a structure of a wireless power transmitter in which a feeder **2410** and a resonator **2420** do not have a common ground. Referring to FIG. **24**A, as an input current flows into a feeder **2410** through a terminal labeled "+" and out of the feeder **2410** through a terminal labeled "−", a magnetic field **2430** is formed by the input current. A direction **2431** of the magnetic field **2430** inside the feeder **2410** is into the plane of FIG. **24**A, and has a phase that is opposite to a phase of a direction **2433** of the magnetic field **2430** outside the feeder **2410**. The magnetic field **2430** formed by the feeder **2410** induces a current to flow in a resonator **2420**. The direction of the induced current in the resonator **2420** is opposite to a direction of the input current in the feeder **2410** as indicated by the dashed arrows in FIG. **24**A.

The induced current in the resonator **2420** forms a magnetic field **2440**. Directions of the magnetic field **2440** are the same at all positions inside the resonator **2420**. Accordingly, a direction **2441** of the magnetic field **2440** formed by the resonator **2420** inside the feeder **2410** has the same phase as a direction **2443** of the magnetic field **2440** formed by the resonator **2420** outside the feeder **2410**.

Consequently, when the magnetic field **2430** formed by the feeder **2410** and the magnetic field **2440** formed by the resonator **2420** are combined, a strength of the total magnetic field inside the resonator **2420** decreases inside the feeder **2410** and increases outside the feeder **2410**. In an example in which power is supplied to the resonator **2420** through the feeder **2410** configured as illustrated in FIG. **24**A, the strength of the total magnetic field decreases in the center of the resonator **2420**, but increases outside the resonator **2420**. In another example in which a magnetic field is randomly distributed in the resonator **2420**, it is difficult to perform impedance matching since an input impedance will frequently vary. Additionally, when the strength of the total magnetic field increases, an efficiency of wireless power transmission increases. Conversely, when the strength of the total magnetic field is decreases, the efficiency of wireless power transmission decreases. Accordingly, the power transmission efficiency may be reduced on average.

FIG. **24**B illustrates an example of a structure of a wireless power transmitter in which a resonator **2450** and a feeder **2460** have a common ground. The resonator **2450** includes a capacitor **2451**. The feeder **2460** receives a radio frequency (RF) signal via a port **2461**. When the RF signal is input to the feeder **2460**, an input current is generated in the feeder **2460**. The input current flowing in the feeder **2460** forms a magnetic field, and a current is induced in the resonator **2450** by the magnetic field. Additionally, another magnetic field is formed by the induced current flowing in the resonator **2450**. In this example, a direction of the input current flowing in the feeder **2460** has a phase opposite to a phase of a direction of the induced current flowing in the resonator **2450**. Accordingly, in a region between the resonator **2450** and the feeder **2460**, a direction **2471** of the magnetic field formed by the input current has the same phase as a direction **2473** of the magnetic field formed by the induced current, and thus the strength of the total magnetic field increases in the region between the resonator **2450** and the feeder **2460**. Conversely, inside the feeder **2460**, a direction **2481** of the magnetic field formed by the input current has a phase opposite to a phase of a direction **2483** of the magnetic field formed by the induced current, and thus the strength of the total magnetic field decreases inside the feeder **2460**. Therefore, the strength of the total magnetic field decreases in the center of the resonator **2450**, but increases outside the resonator **2450**.

An input impedance may be adjusted by adjusting an internal area of the feeder **2460**. The input impedance refers to an impedance viewed in a direction from the feeder **2460** to the resonator **2450**. When the internal area of the feeder **2460** is increased, the input impedance is increased. Conversely, when the internal area of the feeder **2460** is decreased, the input impedance is decreased. Because the magnetic field is randomly distributed in the resonator **2450** despite a reduction in the input impedance, a value of the input impedance may vary based on a location of a target device. Accordingly, a separate matching network may be required to match the input impedance to an output impedance of a power amplifier. For example, when the input impedance is increased, a separate matching network may be used to match the increased input impedance to a relatively low output impedance of the power amplifier.

FIGS. **25**A and **25**B illustrate an example of a wireless power transmitter including a resonator and a feeding unit. Referring to FIG. **25**A, the wireless power transmitter includes a resonator **2510** and a feeding unit **2520**. The resonator **2510** further includes a capacitor **2511**. The feeding unit **2520** is electrically connected to both ends of the capacitor **2511**.

FIG. **25**B illustrates, in greater detail, a structure of the wireless power transmitter of FIG. **25**A. The resonator **2510** includes a first transmission line (not identified by a reference numeral in FIG. **25**B, but formed by various elements in FIG. **25**B as discussed below), a first conductor **2541**, a second conductor **2542**, and at least one capacitor **2550**.

The capacitor **2550** is inserted in series between a first signal conducting portion **2531** and a second signal conducting portion **2532**, causing an electric field to be confined within the capacitor **2550**. Generally, a transmission line includes at least one conductor in an upper portion of the transmission line, and at least one conductor in a lower portion of first transmission line. A current may flow through the at least one conductor disposed in the upper portion of the first transmission line, and the at least one conductor disposed in the lower portion of the first transmission line may be electrically grounded. In this example, a conductor disposed in an upper portion of the first transmission line in FIG. **25**B is separated into two portions that will be referred to as the first signal conducting portion **2531** and the second signal conducting portion **2532**. A conductor disposed in a lower portion of the first transmission line in FIG. **25**B will be referred to as a first ground conducting portion **2533**.

As illustrated in FIG. **25**B, the resonator **2510** has a generally two-dimensional (2D) structure. The first transmission line includes the first signal conducting portion **2531** and the second signal conducting portion **2532** in the upper portion of the first transmission line, and includes the first ground conducting portion **2533** in the lower portion of the first transmission line. The first signal conducting portion **2531** and the second signal conducting portion **2532** are disposed to face the first ground conducting portion **2533**. A current flows through the first signal conducting portion **2531** and the second signal conducting portion **2532**.

One end of the first signal conducting portion **2531** is connected to one end of the first conductor **2541**, the other end of the first signal conducting portion **2531** is connected to the capacitor **2550**, and the other end of the first conductor **2541** is connected to one end of the first ground conducting portion **2533**. One end of the second signal conducting portion **2532** is connected to one end of the second conductor **2542**, the other end of the second signal conducting portion **2532** is connected to the other end of the capacitor **2550**, and the other end of the second conductor **2542** is connected to the other end of the ground conducting portion **2533**. Accordingly, the first signal conducting portion **2531**, the second signal conducting portion **2532**, the first ground conducting portion **2533**, the first conductor **2541**, and the second conductor **2542** are connected to each other, causing the resonator **2510** to have an electrically closed loop structure. The term "loop structure" includes a polygonal structure, a circular structure, a rectangular structure, and any other geometrical structure that is closed, i.e., that does not have any opening in its perimeter. The expression "having a loop structure" indicates a structure that is electrically closed.

The capacitor **2550** is inserted into an intermediate portion of the first transmission line. In the example in FIG. **25**B, the capacitor **2550** is inserted into a space between the first signal conducting portion **2531** and the second signal conducting portion **2532**. The capacitor **2550** may be a lumped element capacitor, a distributed capacitor, or any other type of capacitor known to one of ordinary skill in the art. For example, a distributed element capacitor may include a zigzagged conductor line and a dielectric material having a relatively high permittivity disposed between parallel portions of the zigzagged conductor line.

The capacitor **2550** inserted into the first transmission line may cause the resonator **2510** to have a characteristic of a metamaterial. A metamaterial is a material having a predetermined electrical property that is not found in nature, and thus may have an artificially designed structure. All materials existing in nature have a magnetic permeability and permittivity. Most materials have a positive magnetic permeability and/or a positive permittivity.

For most materials, a right-hand rule may be applied to an electric field, a magnetic field, and a Poynting vector of the materials, so the materials may be referred to as right-handed materials (RHMs). However, a metamaterial that has a magnetic permeability and/or a permittivity that is not found in nature, and may be classified into an epsilon negative (ENG) material, a mu negative (MNG) material, a double negative (DNG) material, a negative refractive index (NRI) material, a left-handed (LH) material, and other metamaterial classifications known to one of ordinary skill in the art based on a sign of the magnetic permeability of the metamaterial and a sign of the permittivity of the metamaterial.

If the capacitor **2550** is a lumped element capacitor and a capacitance of the capacitor **2550** is appropriately determined, the resonator **2510** may have a characteristic of a metamaterial. If the resonator **2510** is caused to have a negative magnetic permeability by appropriately adjusting the capacitance of the capacitor **2550**, the resonator **2510** may also be referred to as an MNG resonator. Various criteria may be applied to determine the capacitance of the capacitor **2550**. For example, the various criteria may include a criterion for enabling the resonator **2510** to have the characteristic of the metamaterial, a criterion for enabling the resonator **2510** to have a negative magnetic permeability at a target frequency, a criterion for enabling the resonator **2510** to have a zeroth order resonance characteristic at the target frequency, and any other suitable criterion. Based on any one or any combination of the aforementioned criteria, the capacitance of the capacitor **2550** may be appropriately determined.

The resonator **2510**, hereinafter referred to as the MNG resonator **2510**, may have a zeroth order resonance characteristic of having a resonant frequency when a propagation constant is "0". If the MNG resonator **2510** has the zeroth order resonance characteristic, the resonant frequency is independent of a physical size of the MNG resonator **2510**. By changing the capacitance of the capacitor **2550**, the resonant frequency of the MNG resonator **2510** may be changed without changing the physical size of the MNG resonator **2510**.

In a near field, the electric field is concentrated in the capacitor **2550** inserted into the first transmission line, causing the magnetic field to become dominant in the near field. The MNG resonator **2510** has a relatively high Q-factor when the capacitor **2550** is a lumped element, thereby increasing a power transmission efficiency. The Q-factor indicates a level of an ohmic loss or a ratio of a reactance with respect to a resistance in the wireless power transmission. As will be understood by one of ordinary skill in the art, the efficiency of the wireless power transmission will increase as the Q-factor increases.

Although not illustrated in FIG. **25**B, a magnetic core passing through the MNG resonator **2510** may be provided to increase a power transmission distance.

Referring to FIG. **25**B, the feeding unit **2520** includes a second transmission line (not identified by a reference numeral in FIG. **25**B, but formed by various elements in FIG. **25**B as discussed below), a third conductor **2571**, a fourth conductor **2572**, a fifth conductor **2581**, and a sixth conductor **2582**.

The second transmission line includes a third signal conducting portion **2561** and a fourth signal conducting portion **2562** in an upper portion of the second transmission line, and includes a second ground conducting portion **2563** in a lower portion of the second transmission line. The third signal conducting portion **2561** and the fourth signal conducting portion **2562** are disposed to face the second ground conducting portion **2563**. A current flows through the third signal conducting portion **2561** and the fourth signal conducting portion **2562**.

One end of the third signal conducting portion **2561** is connected to one end of the third conductor **2571**, the other end of the third signal conducting portion **2561** is connected to one end of the fifth conductor **2581**, and the other end of the third conductor **2571** is connected to one end of the second ground conducting portion **2563**. One end of the fourth signal conducting portion **2562** is connected to one end of the fourth conductor **2572**, the other end of the fourth signal conducting portion **2562** is connected to one end the sixth conductor **2582**, and the other end of the fourth conductor **2572** is connected to the other end of the second ground conducting portion **2563**. The other end of the fifth conductor **2581** is connected to the first signal conducting portion **2531** at or near where the first signal conducting portion **2531** is connected to one end of the capacitor **2550**, and the other end of the sixth conductor **2582** is connected to the second signal conducting portion **2532** at or near where the second signal conducting portion **2532** is connected to the other end of the capacitor **2550**. Thus, the fifth conductor **2581** and the sixth conductor **2582** are connected in parallel to both ends of the capacitor **2550**. The fifth conductor **2581** and the sixth conductor **2582** are used as an input port to receive an RF signal as an input.

Accordingly, the third signal conducting portion **2561**, the fourth signal conducting portion **2562**, the second ground conducting portion **2563**, the third conductor **2571**, the fourth conductor **2572**, the fifth conductor **2581**, the sixth conductor **2582**, and the resonator **2510** are connected to each other, causing the resonator **2510** and the feeding unit **2520** to have an electrically closed loop structure. The term "loop structure" includes a polygonal structure, a circular structure, a rectangular structure, and any other geometrical structure that is closed, i.e., that does not have any opening in its perimeter. The expression "having a loop structure" indicates a structure that is electrically closed.

If an RF signal is input to the fifth conductor **2581** or the sixth conductor **2582**, input current flows through the feeding unit **2520** and the resonator **2510**, generating a magnetic field that induces a current in the resonator **2510**. A direction of the input current flowing through the feeding unit **2520** is identical to a direction of the induced current flowing through the resonator **2510**, thereby causing a strength of a total magnetic field to increase in the center of the resonator **2510**, and decrease near the outer periphery of the resonator **2510**.

An input impedance is determined by an area of a region between the resonator **2510** and the feeding unit **2520**. Accordingly, a separate matching network used to match the input impedance to an output impedance of a power amplifier may not be necessary. However, if a matching network is used, the input impedance may be adjusted by adjusting a size of the feeding unit **2520**, and accordingly a structure of the matching network may be simplified. The simplified structure of the matching network may reduce a matching loss of the matching network.

The second transmission line, the third conductor **2571**, the fourth conductor **2572**, the fifth conductor **2581**, and the sixth conductor **2582** of the feeding unit may have a structure identical to the structure of the resonator **2510**. For example, if the resonator **2510** has a loop structure, the feeding unit **2520** may also have a loop structure. As another example, if the resonator **2510** has a circular structure, the feeding unit **2520** may also have a circular structure.

FIG. **26**A illustrates an example of a distribution of a magnetic field inside a resonator produced by feeding of a feeding unit. FIG. **26**A more simply illustrates the resonator **2510** and the feeding unit **2520** of FIGS. **25**A and **25**B, and the names of the various elements in FIG. **25**B will be used in the following description of FIG. **26**A without reference numerals.

A feeding operation may be an operation of supplying power to a source resonator in wireless power transmission, or an operation of supplying AC power to a rectification unit in wireless power transmission. FIG. **26**A illustrates a direction of input current flowing in the feeding unit, and a direction of induced current flowing in the source resonator. Additionally, FIG. **26**A illustrates a direction of a magnetic field formed by the input current of the feeding unit, and a direction of a magnetic field formed by the induced current of the source resonator.

Referring to FIG. **26**A, the fifth conductor or the sixth conductor of the feeding unit **2520** may be used as an input port **2610**. In FIG. **26**A, the sixth conductor of the feeding unit is being used as the input port **2610**. An RF signal is input to the input port **2610**. The RF signal may be output from a power amplifier. The power amplifier may increase and decrease an amplitude of the RF signal based on a power requirement of a target device. The RF signal input to the input port **2610** is represented in FIG. **26**A as an input current flowing in the feeding unit. The input current flows in a clockwise direction in the feeding unit along the second transmission line of the feeding unit. The fifth conductor and the sixth conductor of the feeding unit are electrically connected to the resonator. More specifically, the fifth conductor of the feeding unit is connected to the first signal conducting portion of the resonator, and the sixth conductor of the feeding unit is connected to the second signal conducting portion of the resonator. Accordingly, the input current flows in both the resonator and the feeding unit. The input current flows in a counterclockwise direction in the resonator along the first transmission line of the resonator. The input current flowing in the resonator generates a magnetic field, and the magnetic field induces a current in the resonator due to the magnetic field. The induced current flows in a clockwise direction in the resonator along the first transmission line of the resonator. The induced current in the resonator transfers energy to the capacitor of the resonator, and also generates a magnetic field. In FIG. **26**A, the input current flowing in the feeding unit and the resonator is indicated by solid lines with arrowheads, and the induced current flowing in the resonator is indicated by dashed lines with arrowheads.

A direction of a magnetic field generated by a current is determined based on the right-hand rule. As illustrated in FIG. **26**A, within the feeding unit, a direction **2621** of the magnetic field generated by the input current flowing in the feeding unit is identical to a direction **2623** of the magnetic field generated by the induced current flowing in the resonator. Accordingly, a strength of the total magnetic field may increases inside the feeding unit.

In contrast, as illustrated in FIG. **26**A, in a region between the feeding unit and the resonator, a direction **2633** of the magnetic field generated by the input current flowing in the feeding unit is opposite to a direction **2631** of the magnetic field generated by the induced current flowing in the source resonator. Accordingly, the strength of the total magnetic field decreases in the region between the feeding unit and the resonator.

Typically, in a resonator having a loop structure, a strength of a magnetic field decreases in the center of the resonator, and increases near an outer periphery of the resonator. However, referring to FIG. **26**A, since the feeding unit is electrically connected to both ends of the capacitor of the resonator, the direction of the induced current in the resonator is identical to the direction of the input current in the feeding unit. Since the direction of the induced current in the resonator is identical to the direction of the input current in the feeding unit, the strength of the total magnetic field increases inside the feeding unit, and decreases outside the feeding unit. As a result, due to the feeding unit, the strength of the total magnetic field increases in the center of the resonator having the loop structure, and decreases near an outer periphery of the resonator, thereby compensating for the normal characteristic of the resonator having the loop structure in which the strength of the magnetic field decreases in the center of the resonator, and increases near the outer periphery of the resonator. Thus, the strength of the total magnetic field may be constant inside the resonator.

A power transmission efficiency for transferring wireless power from a source resonator to a target resonator is proportional to the strength of the total magnetic field generated in the source resonator. Accordingly, when the strength of the total magnetic field increases inside the source resonator, the power transmission efficiency also increases.

FIG. **26**B illustrates examples of equivalent circuits of a feeding unit and a resonator. Referring to FIG. **26**B, a feeding unit **2640** and a resonator **2650** may be represented by the equivalent circuits in FIG. **26**B. The feeding unit **2640** is represented as an inductor having an inductance $L_f$, and the resonator **2650** is represented as a series connection of an inductor having an inductance L coupled to the inductance $L_f$ of the feeding unit **2640** by a mutual inductance M, a capacitor having a capacitance C, and a resistor having a resistance R. An example of an input impedance $Z_{in}$ viewed in a direction from the feeding unit **2640** to the resonator **2650** may be expressed by the following Equation 4:

$$Z_{in} = \frac{(\omega M)^2}{Z} \quad \text{[Equation 4]}$$

In Equation 4, M denotes a mutual inductance between the feeding unit **2640** and the resonator **2650**, ω denotes a resonant frequency of the feeding unit **2640** and the resonator **2650**, and Z denotes an impedance viewed in a direction from the resonator **2650** to a target device. As can be seen from Equation 4, the input impedance $Z_{in}$ is proportional to the square of the mutual inductance M. Accordingly, the input impedance $Z_{in}$ may be adjusted by adjusting the mutual inductance M. The mutual inductance M depends on an area of a region between the feeding unit **2640** and the resonator **2650**. The area of the region between the feeding unit **2640** and the resonator **2650** may be adjusted by adjusting a size of the feeding unit **2640**, thereby adjusting the mutual inductance M and the input impedance $Z_{in}$. Since the input impedance $Z_{in}$ may be adjusted by adjusting the size of the feeding unit **2640**, it may be unnecessary to use a separate matching network to perform impedance matching with an output impedance of a power amplifier.

In a target resonator and a feeding unit included in a wireless power receiver, a magnetic field may be distributed as illustrated in FIG. **26**A. For example, the target resonator may receive wireless power from a source resonator via magnetic coupling. The received wireless power induces a current in the target resonator. The induced current in the target resonator generates a magnetic field, which induces a current in the feeding unit. If the target resonator is connected to the feeding unit as illustrated in FIG. **26**A, a direction of the induced current flowing in the target resonator will be identical to a direction of the induced current flowing in the feeding unit. Accordingly, for the reasons discussed above in connection with FIG. **26**A, a strength of the total magnetic field will increase inside the feeding unit, and will decrease in a region between the feeding unit and the target resonator.

FIG. **27** is a diagram illustrating an example of an electric vehicle charging system. Referring to FIG. **27**, an electric vehicle charging system **2700** includes a source system **2710**, a source resonator **2720**, a target resonator **2730**, a target system **2740**, and an electric vehicle battery **2750**.

In one example, the electric vehicle charging system **2700** has a structure similar to the structure of the wireless power transmission and charging system of FIG. **1**. The source system **2710** and the source resonator **2720** in the electric vehicle charging system **2700** operate as a source. The target resonator **2730** and the target system **2740** in the electric vehicle charging system **2700** operate as a target.

In one example, the source system **2710** includes an alternating current-to-direct current (AC/DC) converter, a power detector, a power converter, a control and communication (control/communication) unit similar to those of the source device **110** of FIG. **1**. In one example, the target system **2740** includes a rectification unit, a DC-to-DC (DC/DC) converter, a switch unit, a charging unit, and a control/communication unit similar to those of the target device **120** of FIG. **1**. The electric vehicle battery **2750** is charged by the target system **2740**. The electric vehicle charging system **2700** may use a resonant frequency in a band of a few kHz to tens of MHz.

The source system **2710** generates power based on a type of the vehicle being charged, a capacity of the electric vehicle battery **2750**, and a charging state of the electric vehicle battery **2750**, and wirelessly transmits the generated power to the target system **2740** via a magnetic coupling between the source resonator **2720** and the target resonator **2730**.

The source system **2710** may control an alignment of the source resonator **2720** and the target resonator **2730**. For example, when the source resonator **2720** and the target resonator **2730** are not aligned, the controller of the source system **2710** may transmit a message to the target system **2740** to control the alignment of the source resonator **2720** and the target resonator **2730**.

For example, when the target resonator **2730** is not located in a position enabling maximum magnetic coupling, the source resonator **2720** and the target resonator **2730** are not properly aligned. When a vehicle does not stop at a proper position to accurately align the source resonator **2720** and the target resonator **2730**, the source system **2710** may instruct a position of the vehicle to be adjusted to control the source resonator **2720** and the target resonator **2730** to be aligned. However, this is just an example, and other methods of aligning the source resonator **2720** and the target resonator **2730** may be used.

The source system **2710** and the target system **2740** may transmit or receive an ID of a vehicle and exchange various messages by performing communication with each other.

The descriptions of FIGS. **2** through **26**B are also applicable to the electric vehicle charging system **2700**. However, the electric vehicle charging system **2700** may use a resonant frequency in a band of a few kHz to tens of MHz, and may wirelessly transmit power that is equal to or higher than tens of watts to charge the electric vehicle battery **2750**.

According to the teachings above, there is provided a wireless power transmission system including a source that selects a channel with little interference by neighboring communication devices, from among channels available for communication, and that transmits a channel seizure signal with a predetermined intensity. When an intensity of the channel seizure signal is greater than a reference value, a target may determine a channel corresponding to the channel seizure signal, to be a communication channel. Thus, it is possible to prevent the target from incorrectly accessing the source.

Additionally, according to various examples, in a wireless power transmission system, a source may transmit an access standard instruction, and a target may transmit a response signal only when a reference requested by the access standard instruction is satisfied. Thus, it is possible to prevent a plurality of targets from colliding with each other.

Furthermore, according to various examples, in a wireless power transmission system, a source may compare power used to transmit an instruction via a communication channel, with power received by a target, and may determine whether the target incorrectly accesses the source. Moreover, according to various examples, in a wireless power transmission system, a source may compare wirelessly transmitted power with power transferred to a load of a target, in a charging mode, and may determine whether the target incorrectly accesses the source.

The units described herein may be implemented using hardware components and software components. For example, the hardware components may include microphones, amplifiers, band-pass filters, audio to digital convertors, and processing devices. A processing device may be implemented using one or more general-purpose or special purpose computers, such as, for example, a processor, a controller and an arithmetic logic unit, a digital signal processor, a microcomputer, a field programmable array, a programmable logic unit, a microprocessor or any other device capable of responding to and executing instructions in a defined manner. The processing device may run an operating system (OS) and one or more software applications that run on the OS. The processing device also may access, store, manipulate, process, and create data in response to execution of the software. For purpose of simplicity, the description of a processing device is used as singular; however, one skilled in the art will appreciated that a processing device may include multiple processing elements and multiple types of processing elements. For example, a processing device may include multiple processors or a processor and a controller. In addition, different processing configurations are possible, such a parallel processors.

The software may include a computer program, a piece of code, an instruction, or some combination thereof, to independently or collectively instruct or configure the processing device to operate as desired. Software and data may be embodied permanently or temporarily in any type of machine, component, physical or virtual equipment, computer storage medium or device, or in a propagated signal wave capable of providing instructions or data to or being interpreted by the processing device. The software also may be distributed over network coupled computer systems so that the software is stored and executed in a distributed fashion. For example, the software and data may be stored by one or more computer readable recording mediums. The computer readable recording medium may include any data storage device that can store data which can be thereafter read by a computer system or processing device. Examples of the non-transitory computer readable recording medium include read-only memory (ROM), random-access memory (RAM), CD-ROMs, magnetic tapes, floppy disks, optical data storage devices. Also, functional programs, codes, and code segments accomplishing the examples disclosed herein can be easily construed by programmers skilled in the art to which the examples pertain based on and using the flow diagrams and block diagrams of the figures and their corresponding descriptions as provided herein.

As a non-exhaustive illustration only, a terminal or device described herein may refer to mobile devices such as a cellular phone, a personal digital assistant (PDA), a digital camera, a portable game console, and an MP3 player, a portable/personal multimedia player (PMP), a handheld e-book, a portable laptop PC, a global positioning system (GPS) navigation, a tablet, a sensor, and devices such as a desktop PC, a high definition television (HDTV), an optical disc player, a setup box, a home appliance, and the like that are capable of wireless communication or network communication consistent with that which is disclosed herein.

A number of examples have been described above. Nevertheless, it will be understood that various modifications may be made. For example, suitable results may be achieved if the described techniques are performed in a different order and/or if components in a described system, architecture, device, or circuit are combined in a different manner and/or replaced or supplemented by other components or their equivalents. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

**1**. A communication apparatus in a wireless power transmission system, the communication apparatus comprising:

a channel search unit configured to search for communication channels other than a channel used in wireless power transmission, and measure state information of the communication channels;

a channel determining unit configured to determine a communication channel available for communication with a target device based on the measured state information;

a communication unit configured to transmit an access instruction to the target device using the determined communication channel; and

a controller configured to determine whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access instruction is received.

**2**. The communication apparatus of claim **1**, wherein the communication apparatus is configured to:

detect the target device in a wireless power transmission region of the communication apparatus.

**3**. The communication apparatus of claim **1**, wherein the channel search unit comprises:

a channel measuring unit configured to measure intensities of interference signals of the respective communication channels.

**4**. The communication apparatus of claim **3**, wherein the channel measuring unit is further configured to:

measure the intensities for a predetermined period of time.

**5**. The communication apparatus of claim **3**, wherein the channel determining unit is further configured to:

determine a communication channel comprising an intensity of an interference signal that is less than or equal to a predetermined value, among the measured intensities, to be the communication channel available for communication with the target device.

**6**. The communication apparatus of claim **3**, wherein the channel determining unit is further configured to:

determine a communication channel comprising an intensity of an interference signal that is lowest in value, among the measured intensities, to be the communication channel available for communication with the target device if each of the intensities are greater than or equal to a channel selection reference level.

**7**. The communication apparatus of claim **1**, wherein the communication unit is further configured to:

transmit a channel seizure signal to the target device, the channel seizure signal comprising a predetermined intensity.

**8**. The communication apparatus of claim **7**, wherein the channel seizure signal is a continuous wave (CW) signal comprising a predetermined intensity and a power greater than a communication signal of a direct-sequence spread spectrum (DSSS).

**9**. The communication apparatus of claim **1**, wherein the controller is further configured to:

assign a control identifier (ID) to the target device if the response signal is received.

**10**. The communication apparatus of claim **1**, wherein the communication unit is further configured to:

transmit a signal to request information on a power required by the target device using a communication frequency of the determined communication channel.

**11**. The communication apparatus of claim **10**, wherein the controller is further configured to:

determine an amount of a wireless power to be transmitted by the communication apparatus based on the information regarding the power required by the target device; and

control a wireless power output from the communication apparatus based on the determined amount of the wireless power.

**12**. The communication apparatus of claim **1**, wherein the channel search unit is further configured to:

search for the communication channels based on a search table set based on a type of the communication apparatus, or a unique ID assigned to the communication apparatus.

**13**. The communication apparatus of claim **1**, wherein the controller is further configured to:

control the channel search unit to search for the communication channels, regardless of whether the target device is waked up.

**14**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine whether the communication apparatus is accessed by the target device based on information on a power of a communication output of the communication apparatus in the determined communication channel, and information on a power of the communication output received by the target device.

**15**. The communication apparatus of claim **14**, wherein the controller is further configured to:

control the channel search unit to search for the communication channels based on a channel search start command if the communication apparatus is not accessed by the target device; and

control the channel search unit to search for the communication channels based on an amount of a change in a current output from the communication apparatus if the communication apparatus is accessed by the target device.

**16**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine a difference between a wireless power transmitted by the communication apparatus and a power transferred to a load of the target device; and

determine whether the target device incorrectly accesses the communication apparatus based on the determined difference.

**17**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine a difference between a time in which an amount of a wireless power transmitted by the communication apparatus is changed to a predetermined value, and a time in which an amount of a power transferred to a load of the target device is changed; and

determine whether the target device incorrectly accesses the communication apparatus based on the determined difference.

**18**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine a power of a communication output in the determined communication channel based on a table to which an intensity of an interference signal in the determined communication channel, and a power of an output signal required to transmit data within a predetermined error range, are mapped.

**19**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine a time required to measure intensities of interference signals of the respective communication channels.

**20**. The communication apparatus of claim **1**, wherein the controller is further configured to:

determine to change the determined communication channel to another communication channel if an error in the determined communication channel between the communication apparatus and the target device is greater than a predetermined value, or if an intensity of an interference signal of the determined communication channel is greater than a predetermined value; and

transmit a channel change request instruction to the target device.

**21**. A communication apparatus in a wireless power transmission system, the communication apparatus comprising:

a channel search unit configured to search for communication channels other than a channel used in wireless power transmission, and measure state information of the communication channels;

a channel determining unit configured to determine a communication channel available for communication with a source device based on the measured state information; and

a controller configured to determine whether to communicate with the source device using the determined communication channel based on whether an access instruction is received from the source device using the determined communication channel.

**22**. The communication apparatus of claim **21**, wherein the controller is configured to:

determine whether the access instruction is received from the source device using the determined communication channel within a reference time.

23. The communication apparatus of claim 22, further comprising:

a communication unit configured to transmit, to the source device, a response signal corresponding to the access instruction if the access instruction is received within the reference time.

24. The communication apparatus of claim 23, wherein the communication unit is further configured to:

receive, from the source device, a control ID assigned to the communication apparatus and that corresponds to the response signal.

25. The communication apparatus of claim 22, wherein the channel search unit is further configured to:

search for another communication channel, and measure state information of the other communication channel, if the access instruction is not received within the reference time.

26. The communication apparatus of claim 21, wherein:

the channel search unit is further configured to measure intensities of channel seizure signals of the respective communication channels that are transmitted by the source device; and

the channel determining unit is further configured to determine a communication channel comprising an intensity of a channel seizure signal that is greater than a predetermined value, among the intensities, to be the communication channel available for communication with the source device.

27. The communication apparatus of claim 26, wherein the channel seizure signal is a continuous wave (CW) signal comprising a predetermined intensity and a power greater than a communication signal of a direct-sequence spread spectrum (DSSS).

28. The communication apparatus of claim 21, wherein:

the communication apparatus is configured to receive channel seizure signals from source devices; and

the controller is further configured to select one of the source devices using a communication channel comprising an intensity of a channel seizure signal that is greatest in value, from among the source devices, and determine to receive a wireless power from the selected one of the source devices.

29. The communication apparatus of claim 28, wherein the channel determining unit is further configured to:

determine the communication channel used by the selected one of the source devices to be a communication channel available for communication with the selected one of the source devices.

30. The communication apparatus of claim 21, wherein the channel search unit is further configured to:

search for the communication channels based on a search table set based on a type of the communication apparatus, or a unique ID assigned to the communication apparatus.

31. The communication apparatus of claim 21, further comprising:

a direct current (DC)-to-DC (DC/DC) converter; and

a load,

wherein the controller is further configured to determine a power required by the communication apparatus based on a power measured at an input end of the DC/DC converter, a power measured at an output end of the DC/DC converter, and a power transferred to the load.

32. A communication method in a wireless power transmission system, the communication method comprising:

searching for communication channels other than a channel used in wireless power transmission;

measuring state information of the communication channels;

determining a communication channel available for communication with a target device based on the measured state information;

transmitting an access instruction to the target device using the determined communication channel; and

determining whether to communicate with the target device using the determined communication channel based on whether a response signal corresponding to the access instruction is received.

33. The communication method of 32, further comprising:

transmitting a channel seizure signal to the target device, the channel seizure signal comprising a predetermined intensity.

34. The communication method of claim 32, wherein the measuring of the state information comprises:

measuring intensities of interference signals of the respective communication channels.

35. The communication method of claim 34, wherein the determining of the communication channel comprises:

determining a communication channel comprising an intensity of an interference signal that is less than or equal to a predetermined value, among the measured intensities, to be the communication channel available for communication with the target device.

36. A communication method in a wireless power transmission system, the communication method comprising:

searching for communication channels other than a channel used in wireless power transmission;

measuring state information of the communication channels;

determining a communication channel available for communication with a source device based on the measured state information; and

determining whether to communicate with the source device using the determined communication channel based on whether an access instruction is received from the source device using the determined communication channel.

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